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THE
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OF
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THE AERIAL WORLD:

A POPULAR ACCOUNT

OF THE

PHENOMENA AND LIFE OF THE ATMOSPHERE.

BY

eorge Ludwig

G. HARTWIG, M. & P.D.

AUTHOR OF

'THE SEA AND ITS LIVING WONDERS' 'THE TROPICAL WORLD' 'THE POLAR WORLD'
AND 'THE SUBTERRANEAN WORLD.'

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PREFACE.

THE plan which I proposed to myself in writing this book was not to enter into minute details or learned disquisitions such as would be required in a Handbook of Meteorology. My less ambitious aim was merely to give a general view of the phenomena of the atmosphere, to point out the manifold relations between the aerial ocean and man, and to describe the life of which it is the ever busy scene. If after a perusal of its contents the reader should find his interest in the great pages of nature more keenly awakened than it may previously have been, and thus be led to deeper thought and further enquiry, I shall not consider as ill-spent the time and labour I have bestowed upon its composition.

G. HARTWIG.

Salon Villa, Ludwigsburg, Würtemberg:
October 31, 1874.

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THE AERIAL WORLD.

CHAPTER I.

THE MAGNITUDE AND PRESSURE OF THE ATMOSPHERE.

The Magnitude and Weight of the Atmosphere compared with those of the Ocean—Attempts to Measure the Height of the Atmosphere—The Barometer—Its Discovery by Torricelli—Accidental and Periodical Fluctuations of the Barometer—The Barometer as a Means for Measuring Heights—Effect of Diminished Atmospherical Pressure on the Boiling Point of Water—Pressure of the Atmosphere on the Human Body—Why not Felt?—Experiments on Atmospherical Pressure—Effects of Rarefied Air on the Human Constitution—The Mountain Sickness—Humboldt on the Pichincha—Lloyd in the Himalaya Mountains—The Highest Balloon Ascents—Gay-Lussac—Barral and Bixio—Glaisher and Coxwell—Seven Miles high—Weight of the Atmosphere.

GREAT is the ocean, but still greater the aerial sea which envelopes the whole earth. The former covers with its floods only three-fourths of the surface of our planet, and its average depth is scarcely more than 10,000 feet; but the atmosphere spreads its invisible canopy over sea and land, and the height of its uppermost strata is reckoned by miles. In the wide regions of this transparent world many water-oceans might roll their waves, and the domains of the finny tribes are but small when compared with those of the light winged birds.

But though the atmosphere occupies a much greater space than the ocean, the latter surpasses the aerial sea by far in density and weight. For the pressure which the atmosphere exerts upon the surface of the earth at the level of the ocean is only equal to that of an aqueous sea thirty-two feet deep; and thus, supposing it to be suddenly changed into water, and its floods added to those of the ocean, the increase would merely inundate the lowlands of our globe.

How high is the atmosphere? How great is the distance from its lowest strata resting on the surface of the sea to its extreme limits bordering on the unknown regions of interstellar space? This could easily be ascertained if the atmosphere had the same density and weight throughout its whole extent, for as air is 771 times lighter than water, a simple reckoning would at once answer the question.

But air is a very elastic body, and, in consequence of the earth's attraction, each superincumbent stratum presses upon all those below it, and by thus forcing them to occupy a narrower space, increases their density. Hence the atmosphere becomes lighter and more rarefied as its distance from the surface of the sea increases, but this diminution of weight does not take place in gradual and fixed proportions. As the air expands, its expansive force decreases and is still further weakened by the low temperature of the upper regions of the air. The contact of the cold or heated earth, and the varying tension of the constantly changing quantity of aqueous vapour contained in the atmosphere, likewise hinder the exact calculation of its weight at different distances above the level of the sea, so that for want of a fixed and undeviating rule for the measurement of the ethereal heights of air, we must be satisfied with more or less probable conjectures.

Attempts have been made to measure the height of the atmosphere by studying the phenomena of twilight, but the calculations founded on this basis lead to very different results. Arago found 7·92 geographical miles to be the extreme limit where the air has still sufficient density to reflect crepuscular light; while, from similar observations made on the summit of the Faulhorn, M. Bravais obtained a height of seventy-one and a-half miles. This is about the point above which it is supposed the friction of the air will not set light to a meteor; but it is evident that beyond these heights there may still be a vast space occupied by extremely rarefied air.

So much is certain, that though our knowledge of the upper regions of the atmosphere is very imperfect, the pressure of the air beyond a height of thirty or forty miles must be inappreciable by the most delicate physical instruments, and that whatever the volume of those upper aerial domains may be, they can form but an utterly insignificant portion of the whole atmospheric mass.

The barometer teaches us that the pressure or density of the air at equal altitudes is subject to perpetual fluctuations. This simple and invaluable instrument, which reveals to us every pulsation, as it were, of the constantly wavering atmospherical ocean, was invented about the year 1643 by the Florentine Evangelista Torricelli, who thereby laid the first foundation of scientific meteorology. The train of thought which led this great physical investigator to his far-reaching discovery is thus lucidly described by a master hand :—

'It was known before the sixteenth century that the end of an open tube being dipped into water, on drawing an air-tight piston up the tube, the water follows the piston, and this fact had been turned to account in the construction of the common pump. The effect was explained at the time by the maxim, "Nature abhors a vacuum." It was not known that there was any limit to the height to which the water would ascend, until on one occasion the gardeners of Florence, while attempting to raise the water a very great elevation, found that the column ceased at a height of thirty-two feet. Beyond this all the skill of the pump-maker could not get it to rise. The fact was brought to the notice of Galileo; and he, soured by a world which had not treated his science over kindly, is said to have twitted the philosophy of the time by remarking that "Nature evidently abhorred a vacuum only to a height of thirty-two feet." But Galileo did not solve the problem taken up by his pupil Torricelli, who pondered it, and, while he did so, various thoughts regarding it arose in his mind. It occurred to him that the water might be forced up in the tube by a pressure applied to the surface of the water outside. But where, under the actual circumstances, was such a pressure to be found? After much reflection, it flashed upon Torricelli that the atmosphere might possibly exert the pressure; that the impalpable air might possess weight, and that a column of water thirty-two feet high might be of the exact weight necessary to hold the pressure of the atmosphere in equilibrium.

'There is much in this process of pondering and its results which it is impossible to analyse. It is by a kind of inspiration that we rise from the wise and sedulous contemplation of facts to the principles on which they depend. The mind is, as it were, a photographic plate, which is gradually cleansed by the effort to think rightly, and which, when so cleansed, and not before, receives impressions from the light of truth. This passage from facts to principles is called induction, which, in its highest form, is inspiration; but, to make it safe, the inward sight must be shown to be in accordance with outward fact. To prove or disprove the induction, we must resort to deduction and experiment.

'Torricelli reasoned thus:—If a column of water thirty-two feet high holds the pressure of the air in equilibrium, a shorter column of a heavier liquid ought to do the same. Now, mercury is thirteen times heavier than water; hence, if my induction be correct, the atmosphere ought to be able to sustain only thirty inches of mercury. Here, then, is a deduction which can be immediately submitted to experiment.

'Torricelli took a glass tube a yard or so in length, closed at one end and opened at the other, and filling it with mercury, he stopped the open end with his thumb and inserted it in a basin filled with the liquid metal. One can imagine the feeling with which Torricelli removed his thumb, and the delight he experienced when he found that his thought had forestalled a fact never before revealed to human eyes. The column sank, but ceased to sink at a height of thirty inches, leaving the Torricellian vacuum overhead.'[1]

The fluctuations of the barometer or of the atmospherical pressure are in part accidental or inconstant, in part periodical or diurnal. Every alteration of the temperature, every change of the wind, every increase or decrease of the aqueous vapour which mingles with the air, mirrors itself in the rise or fall of the mercurial column. But besides these accidental variations, observation has shown that, during the course of each day, the barometer regularly rises and falls. It stands lowest at about four in the afternoon and four in the morning; highest at ten in the evening and ten in the morning, the intervals exhibiting gradually progressive risings and fallings.

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[1] Tyndall's 'Fragments of Science.'

These regular and diurnal fluctuations of the atmospherical pressure might be compared with the ebb and flood of the sea, and, on a superficial view, be attributed to the same cause. That this, however, is not the case, is plainly shown by the circumstance that the tides of the sea daily advance by about fifty minutes, while the periodical changes of the barometer, which depend upon the action of solar heat, and on the degree of tension of the aqueous vapour, constantly occur at the same hours.

In the temperate zones these regular oscillations of the barometer are generally veiled by its more frequent and more powerful accidental perturbations; but within the tropics, where all the atmospherical phenomena are far less variable, they take place with such regularity that a barometer may serve to a certain extent as a time-piece.

The range of barometrical variations, that is, the difference between the greatest and least height, is different in different degrees of latitude. It increases from the equator towards the poles, for while under the former the greatest variations, except under extraordinary circumstances, do not exceed three lines, they amount to an inch and a-half under the tropic of Cancer, and to three inches at 25° from the pole. The mean daily height is the height obtained by dividing the sum of twenty-four successive hourly observations by twenty-four. The mean monthly height is obtained by adding together the mean daily heights for a month, and dividing by thirty. The mean yearly height is similarly obtained.

Humboldt appears first to have remarked that the height of the barometer is lower at the equator than in temperate latitudes. Under the equator, the mean annual height at the level of the sea is 29·84 inches, and between the latitudes 30 and 40 it attains a maximum of 30·04 inches. The general mean at the level of the sea is 29·96 inches. The mean monthly height is greater in winter than in summer, in consequence of the cooler atmosphere.

The barometer not only indicates the perpetual fluctuations which take place in the density of the air on the same spot, it also serves as an instrument for measuring accessible altitudes, since the pressure of the air necessarily diminishes with its elevation above the level of the sea. Armed with a good barometer, the wanderer in the snowy solitudes of the mountain world can ascertain with some degree of accuracy how many thousand feet he has risen above the level of the valley where he began his ascent; or the aeronaut determine the height to which his balloon has carried him into the lifeless wastes of the rarefied atmosphere.

In a letter dated November 15, 1647, the celebrated Pascal, reasoning upon the ground that if the mercurial column be supported by the atmosphere, the higher we ascend in the air the lower the column ought to sink, occasioned his brother-in-law Perrier to carry a barometer to the top of the Puy de Dôme, which is 3,000 feet high. The experiment, however, was only made two years later, on November 19, 1649, when it was found that on the summit of the mountain the barometric column stood lower by three inches and a line and a-half than at its foot. Hence Pascal is generally supposed to have first suggested the application of the barometer to the mensuration of altitudes; but Beriguardus mentions that as early as 1643 the newly invented Torricellian tube had been used in Tuscany for the same purpose.

In consequence of the diminished pressure of the atmosphere on high mountains, the boiling point of water is correspondingly lowered. On an August morning in 1859 the temperature of boiling water on the summit of Mont Blanc (15,784 feet) was found, by Professor Tyndall, to be 184·95° Fahr.; that is, about 27° lower than the boiling point at the sea level. On August 3, 1858, the temperature of boiling water on the summit of the Finsteraarhorn (14,039 feet) was 187° Fahr. On August 10, 1858, the boiling point on the summit of Monte Rosa (15,223 feet) was 184·92° Fahr. The boiling point on Monte Rosa is shown by these observations to be almost the same as it was found to be on Mont Blanc, though the latter exceeds the former in height by 500 feet. The fluctuations of the barometer are, however, quite sufficient to account for this anomaly. The lowering of the boiling point is about 1° Fahr. for every 590 feet of elevation, and hence the temperature of boiling water has not unfrequently been employed for measuring heights. The experiment has, however, great practical difficulties; for though Professor Tyndall, who to his other and more important distinctions adds that of being a first-rate *bergsteiger*, caused water to boil on three of the highest summits of Europe, it is not altogether an easy matter to light a fire on a gusty mountain peak, some 7,000 or 8,000 feet above the level of perpetual snow.

As a curious result of the diminished pressure lowering the boiling point, it may be mentioned that on the Puna,[1] or the high table-lands of Peru, at an elevation of from 10,000 to 14,000 feet above the level of the sea, neither eggs, potatoes, nor meat can be sufficiently boiled; so that whoever wishes to eat a warm dinner on that bleak plateau is obliged to have it baked or roasted.

The monks of St. Bernard, living as they do at an elevation of 8,600 feet, are put to great inconvenience by the same phenomenon, and are compelled to subsist almost entirely on fried, roasted, and baked food. It is said that to make good tea in London, boiling water is essential; and if this be so, it would be vain to expect the beverage 'which cheers but not inebriates' in all its excellence at the hands of the good monks of St. Bernard.

Mr. Darwin relates a humorous instance of the culinary effects of diminished pressure which happened to him while crossing the Andes. 'The potatoes, after remaining for some hours in the boiling water, were nearly as hard as ever. The pot was left on the fire all night, and next morning it was boiled again, but yet the potatoes were not cooked. I found out this, by overhearing my two companions discussing the cause; they had come to the simple conclusion that the "cursed pot" (which was a new one) did not choose to boil potatoes.'

As the pressure of the atmosphere at the level of the sea is equal to that of a column of mercury 30 inches high, and as a cubic inch of mercury weighs 0·49 of a pound, it follows that the pressure of such a column, or of its atmospherical equivalent, on a square inch of surface, is equal to 14·7 lbs. In round numbers, the pressure of the atmosphere is taken at 15 lbs. on the square inch, or at 2,160 lbs. on the square foot. The surface of the body of a man of middle size is about 16 square feet; the pressure, therefore, which a man supports on the surface of his body is 34,560 lbs., or nearly 16 tons. It may be asked how this enormous weight rests upon us without our being in the least aware of it, but it must be remembered that in all directions there are equal and contrary pressures which counterbalance one another. It might also be supposed that the effect of this force acting in all directions would be to press the body together and crush it. But the air which is contained in the organs of our body, being as dense as the external air, cannot be further compressed; the liquids are virtually incompressible, and the solid parts of the skeleton could resist a far greater pressure. The pressure of the atmosphere on the body can thus only become apparent when a vacuum is produced either by means of a cupping vessel or by the air-pump, as, for instance, in the following experiment:—A stout glass cylinder open at both ends being placed on the plate of an air-pump, the upper end of the cylinder is closed by the hand, and a vacuum is made. The hand then becomes pressed by the weight of the atmosphere, and can only be taken away by a great effort. And as the elasticity of the fluid contained in the organ is not counterbalanced by the weight of the atmosphere, the palm of the hand swells, and blood tends to escape from the pores.

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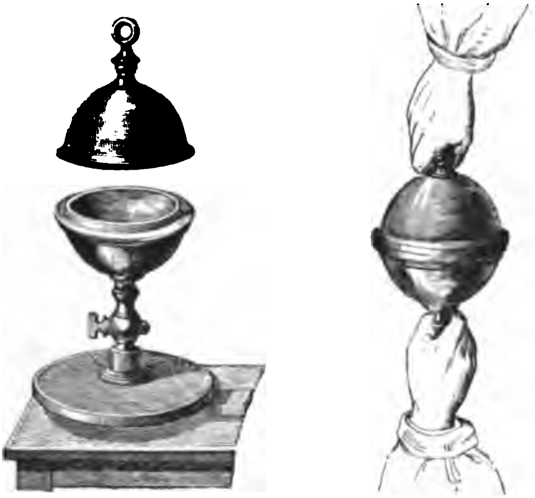
[1] 'The Tropical World,' chap. iii.

EXPERIMENT ON THE PRESSURE OF AIR.

This experiment only serves to illustrate the downward pressure of the atmosphere; but by means of the Magdeburg hemisphere, the invention of which is due to Otto von Guericke, it can be shown that the pressure acts in all directions. This apparatus consists of two hollow brass hemispheres, the edges of which are made to fit tightly, and are well greased. One of the hemispheres is provided with a stop-cock, by which it can be screwed on the air-pump, and on the other there is a handle. As long as the hemispheres contain air they can be separated without difficulty; but when the air in the interior is pumped out, the hemispheres cannot be separated without a powerful effort; and as this is the case in whatever position they are held, it follows that the atmospheric pressure is transmitted in all directions.



MAGDEBURG HEMISPHERES.

As the constant inhalation of a certain quantity of air is a necessary means of life, it follows that its increasing rarefaction, on ascending higher and higher above the level of the sea, will for ever prevent man from penetrating into the unknown regions of the upper atmosphere and submitting its various phenomena to the test of personal investigation. If he endeavours with incredible difficulty to reach the summit of the snowy mountain peaks, which look down like unapproachable pinnacles upon the nether world, symptoms of weakness begin to remind him, at a height of 12,000 or 13,000 feet, that the atmosphere in which he lives is at the same time a prison, which confines him within narrow limits, and encircles him, as it were, with adamantine walls. As he advances, every step grows more and more fatiguing, every effort to ascend becomes more and more arduous, so that in the Andes even the hardiest mountaineer, accustomed from infancy to breathe the light air of the Puna, cannot walk ten paces, after attaining a height of 16,000 feet, without resting several minutes. At the same time, respiration becomes more and more difficult, the pulse beats more and more rapidly, and the heart palpitates with increasing violence. These distressing symptoms are accompanied with a tendency of congestion of the blood to the lungs and brain. Bouguer had several hæmorrhages on the Cordilleras of Quito, although the highest elevation which he attained with his companion La Condamine did not exceed 15,000 feet; and while ascending the Pichincha, Humboldt, at the far inferior height of 13,800 feet, was suddenly seized with giddiness and nausea, and fell down senseless upon the ground. On the Antisana he suffered, indeed, less from the effects of the rarefied atmosphere, though at a height of 17,200 feet; but his young companion, Don Carlos Montufar, bled copiously from the lips.

Animals also feel similar symptoms of indisposition and prostration. In the Highlands of Quito it is uncommonly difficult to make even the strongest horses and mules advance at heights above 13,000 feet. They began to pace more slowly, frequently stand still, tremble all over, and fall upon the ground. If not allowed to rest, they invariably perish. The small and elegant lama, the mountain camel of the Andes, is indeed better able to support the rarefaction of the atmosphere, and, charged with a moderate load, advances briskly as high as the snow line (about 15,000 feet); but at a still greater elevation even this son of the mountains is unable to carry burdens, and refuses to continue his march.

On ascending the Manerang Pass (18,612 feet high), in the Himalaya mountains, Major Lloyd[1] began to feel the effects of the rarefied air at about 15,000 feet. Long before he attained its summit, his respiration became hurried and oppressive, and compelled him to sit down every few yards, and thus only could he inhale a sufficient supply of air. The least motion was attended by debility and mental dejection, and thus he laboured on for two hours. 'It is indisputable,' says the gallant traveller, 'that beyond a certain height the effects of the rarefied air upon the functions of animal life are permanent, and neither custom nor constitution can bear up against them. In our excursion to the peak of Boorendo (19,500 feet), although we were unable to take a dozen steps without being exhausted, and latterly could scarcely move at all, we nevertheless outdid the villagers who accompanied us and reside at the height of 12,000 feet. In the interior of the country, where the soil is remarkably elevated, the most dreadful symptoms are felt in crossing the mountains. At 18,480 feet the barometer in the mean state of the air stands at fifteen inches, so that here we breathe an atmosphere half the density of that at the level of the sea: how, then, can we be surprised at the effects?'

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[1] 'Narrative of a Journey from Cawnpoor to the Boorendo Pass.'

No doubt man possesses an admirable power of adapting himself to every change and variety of climate, and practice and habit may do much towards rendering him more capable of exertion in a highly rarefied air; but still we may confidently assert that even the most robust and best trained pedestrian will never be able to ascend much higher than Boussingault and Hall, who, on December 16, 1831, climbed up the Chimborazo to an elevation of 18,496 French feet, but were then obliged to desist without having reached its summit.

The intelligence of man will certainly in course of time achieve still many a wonderful conquest over matter, and render many of the yet unsubdued powers of nature subject to his dominion; but his physical weakness will ever oppose insurmountable obstacles to his toilsome march above a certain point, and imperatively call out to him, 'Thus far and no farther shalt thou go!'

Quietly seated in a balloon, where, without any bodily exertion, he soars upwards as far as his light air-ship will carry him, he has indeed been enabled to attain heights far superior to those that have been reached on foot by a Boussingault or a Lloyd; but vast aerial regions still extend beyond the most daring flights he has ever thus accomplished, and he soon is forced to quit those cold and repulsive heights for the denser atmosphere which has been assigned to him as his natural domain.

On perusing the annals of aerostation, we find Gay-Lussac in 1804, Messrs. Barral and Bixio in 1850, and Mr. Welsh, of the Kew Observatory, in 1852, ascending to heights of about 23,000 feet; but in their aerial voyage from Wolverhampton to Cold Weston, near Ludlow, on September 5, 1862, Messrs. Glaisher and Coxwell approached the utmost limits, beyond which breathing becomes impossible and life can no longer be sustained.

Up to an elevation of 10,000 feet, these bold aerial navigators remained enveloped in clouds, but on emerging from this misty veil a flood of strong sunlight burst upon them, with a beautiful blue sky, and beneath them lay a magnificent sea of clouds, its surface varied with endless hills, hillocks, and mountain-chains, and with many snow-white tufts rising from it. At an elevation of 19,000 feet Mr. Coxwell was panting for breath, and on reaching the height of four miles the temperature had fallen to 24° below the freezing point of water. When they left the earth at Wolverhampton seven and thirty minutes before, the temperature of the air was 59°, so that they experienced a very rapid transition from summer to the severest winter. But the cold was still increasing as they rose, for having discharged some ballast they in ten minutes attained the altitude of five miles, and the temperature then read 2° below zero. Up to this time, Mr. Glaisher had taken observations with comfort, and experienced no difficulty in breathing, whilst his companion, in consequence of the exertions he had to make in managing the balloon, had breathed with difficulty for some time. More ballast was thrown out, and at the altitude of 29,000 feet, Mr. Glaisher's eyesight began to fail, so that he could not see the column of mercury in the wet bulb thermometer, nor the hands of the watch, nor the fine divisions on any instrument. The sensations he experienced before his consciousness failed him, and those he felt when it gradually returned, he describes as follows :—[1]

'Shortly after I laid my hand upon the table, possessed of its full vigour, but on being desirous of using it I found it powerless—it must have lost its power momentarily; trying to use the other arm I found it powerless also. Then I tried to shake myself, and succeeded, but I seemed to have no limbs. In looking at the barometer, my head fell over my left shoulder. I struggled and shook my body again, but could not move my arms. Getting my head upright for an instant only, it fell on my right shoulder; then I fell backwards, my arm resting against the side of the car, and my head on its edge. In this position my eyes were directed to Mr. Coxwell in the ring, into which he had ascended to re-adjust the entangled valve-line. I endeavoured to speak, but could not. In an instant intense darkness overcame me, but I was still conscious, with as active a brain as at the present moment while writing this. I thought I had been seized with asphyxia, and believed I should experience nothing more, as death would come unless we speedily descended; other thoughts were entering my mind, when I suddenly became unconscious, as on going to sleep. I cannot tell anything of the sense of hearing, as no sound reaches the ear to break the perfect stillness and silence of the region between six and seven miles above the earth.

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[1] 'Travels in the Air.'

'Whilst powerless I heard the words "temperature" and "observation," and I knew Mr. Coxwell was in the car, speaking to and endeavouring to rouse me—therefore consciousness and hearing had returned. I then heard him speak more emphatically, but could not see, speak, or move. Then the instruments became dimly visible, then Mr. Coxwell, and very shortly I saw clearly. Mr. Coxwell told me that while in the ring he felt it piercingly cold, and that on attempting to leave it he found his hands frozen. He had, therefore, to place his arms on the ring and drop down. . . . He wished to approach me, but could not, and when he felt insensibility coming over him too, he became anxious to open the valve. But in consequence of having lost the use of his hands, he could not do this. Ultimately he succeeded by seizing the cord with his teeth, and dipping his head two or three times till the balloon took a decided turn downwards.'

Mr. Glaisher approximately estimates the height to which he rose at 36,000 or 37,000 feet. So much is certain that in this intrepid aerial voyage the unexampled altitude of between six and seven miles was attained; and when we consider upon how slender a thread the life of the aeronauts was hanging (for their death was inevitable if Mr. Coxwell had been unable to open the valve, or had become as insensible as his companion), we may well doubt whether the foolhardy attempt to surpass their soaring flight will ever be made. Science could not possibly benefit by it, for observations are of course quite out of the question when breathing is about to cease.

The weight of the atmosphere can be determined with greater accuracy than its height, as it is equal to that of a stratum of water covering the whole surface of the earth thirty-two feet deep. Such a stratum would weigh about nine and a-half trillions of pounds; and thus a body proverbially light is able to throw an incomparably greater weight into the balance than all the ores and minerals which man since time immemorial has extracted from the bowels of the earth.

CHAPTER II.

INGREDIENTS OF THE ATMOSPHERE.

The four Elements of the Ancients—Air a Mixture of various Gases—Oxygen—Its Qualities—Nitrogen—Ozone—Its characteristic Smell remarked by the Ancients and mentioned in the Odyssey—Carbonic Acid—Its Properties—Diffusion of Gases—Ammonia—Aqueous Vapours—Casual Ingredients of the Atmosphere—Odorous Principles—Their extreme Divisibility—Self-purifying Power of the Atmosphere—The Molecules of the Atmosphere.

THOUGH thousands of years have elapsed since man first appeared upon the stage of life, yet, strange to say, not quite a century has passed since he first gained an insight into the composition of the air he breathes.

The Greek philosophers, who knew but little of the art of interrogating Nature by careful observations or accurate experiments, but whose speculative minds were extremely active in the invention of splendid theories, reckoned air, along with fire, water, and earth, among their four elements whose various combinations gave birth to all other existing substances. These four elements were placed in the universe according to their weight. Earth, as the heaviest, occupied the centre; water, the next in weight to earth, was principally spread over its surface; the lighter air occupied the middle zone of the universe; and fire, the lightest and most volatile of all, reigned in the highest regions, where it formed the sun and the planets. This system served to explain the composition of all the productions of nature. The meteors, for instance, were supposed to consist of fire and air; the inferior animals of earth and water; and man was indebted for the warmth of his blood to the addition of some of the fiery principle to the cold material mass of his body.

For many centuries this ancient theory of the four elements was implicitly believed, until modern chemistry overthrew the whole fallacious fabric, and, dethroning the old elements, set up a far greater number of new ones in their place. As the ancient element earth has been decomposed into numerous metals, united with other primary substances; as water has been found out to be a compound of hydrogen and oxygen; as fire, from being a substance, has been converted into a mode of motion;—so also air has lost its ancient rank as an undecomposable element, and is now known to be a mere mixture of various gases.

To Priestley (born 1733, died 1804), one of the great men who opened the era of modern chemistry, we are indebted for the discovery of oxygen, one of the two constituents of *atmospheric air.* In this gas it was found that combustion took place with extraordinary intensity; even iron wire heated red hot and plunged into it caught fire and burnt away! Other combustibles gave out showers of the most brilliant sparks, and produced the most intense heat when placed in the jar containing it; a lighted taper having been blown out, instantly rekindled when put into it, and blazed with much greater intensity than in air.

Soon afterwards another gas was found also to form a part of the composition of air. This gas was the direct contrast of the other. Instead of increasing the brilliancy of flame, it extinguished it as effectually as if it had been plunged into water. Like the other, it was inodorous and invisible; but while the first exhibited the utmost avidity for combination, this was resolutely indifferent to every substance. Animals were intoxicated when immersed in the first, they were suffocated on immersion into this. Such are the opposing qualities of the important gases, oxygen and nitrogen, which, in the proportion of $\frac{23}{100}$ to $\frac{77}{100}$ in weight and of $\frac{20{\cdot}99}{100{\cdot}00}$ to $\frac{79{\cdot}01}{100{\cdot}00}$ in volume, form the great mass of air we breathe, and though singly incapable of supporting life, are so mingled in the atmosphere—the inertness of nitrogen tempering the active energy of oxygen—as to produce the exact measure necessary for the existence of the whole organic world. Supposing the proportion of oxygen to be raised from one-fifth to one-fourth, a considerable acceleration of the vital process would be the result, and organic life forced to undergo such changes as to produce a total revolution in the existing state of things. On the other hand, life would languish under an augmentation of nitrogen, and either be extinguished altogether, or assume new forms, harmonising with the altered condition of the atmosphere.

Until within the last few years, chemical investigation could find no difference whatever in the relative quantities of these two gases. Gay-Lussac, by means of the balloon, brought down air in a vessel from the height of between three and four miles. On being analysed, it was found to be in no respect different from the air of the lower strata of the atmosphere. De Saussure spent a considerable time on the high Alps in analysing the air of these altitudes, but he also found that air taken from the summit of the Faulhorn was of the precise composition of air at Paris. The air contained in particles of snow was also examined, being expected to furnish a fair sample of the qualities of air in those lofty regions where snow is formed; but in every case the results were similar. In whatever country air was analysed, it was impossible to detect the smallest difference in its composition, and even the air which was spreading the most fatal pestilence, the air of a great and crowded city, the air of a hospital ward, were all found identical as far as their proportions of oxygen and nitrogen went.

But where the utmost accuracy of a Dumas or a Boussingault failed to render appreciable the smallest essential difference between the hot and dusty air of towns and the balmy breathings of a country wind, laden with the odour of a thousand flowers, so great is the perfection to which chemical analysis has now been brought, that errors have since their day gone down from six per cent. to the second place of decimals. Thus Dr. Angus Smith[1] not only tells us that the air of mountains and plains differs from that of towns and dwelling-rooms, but he shows us exactly in what the difference consists. The sea-air on the coast of Scotland contains 20·999 per cent. of oxygen; that of a suburb of Manchester on a wet day, 20·9800; the same on a dry day, 20·947; in Manchester during fog and frost, 20·910; whilst in a sitting-room the quantity is reduced to 20·89; in the pit of a theatre to 20·74; in the Court of Queen's Bench to 20·65; and in the sumpt of a mine to 20·14. Though the differences are minute, they are definite.

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[1] 'Air and Rain, the Beginnings of a Chemical Climatology.' London, 1872.

The air of impure places is universally characterised by a diminished quantity of oxygen. The air of a closet or midden contained only an average of 20·70 per cent., whilst the air of the street contained 20·943. In the open spaces of London, the proportion of oxygen is 20·950 per cent.; in the eastern and crowded districts it is 20·857; in the Metropolitan Railway tunnel it is only 20·70; in the middle of Hyde Park the air is particularly pure, and was found to contain 21·00 per cent. of oxygen. The air contains the largest quantity of oxygen after rain, and the smallest in dull, foggy weather. The senses seem to estimate a difference of only 0·07 per cent., but it is probable that they estimate the impurities produced rather than the loss of oxygen. During a visit to London, Dr. Smith analysed the air of a law-court. One specimen had 20·65 per cent. of oxygen; and a second, taken from the lantern, only 20·490. No such loss of oxygen was found in any factory in Manchester, or in any other inhabited place above ground during the day. To find air similarly degraded, it is necessary to descend the shaft of mines, where the deterioration is the same. Had Dickens known of this circumstance, he might perhaps have made it the subject of some cutting remarks upon his good friends the lawyers.

As in science one discovery leads to another, the researches of the present age have shown us oxygen in a new state, investing it with properties such as were never thought of by Priestley or Lavoisier. The name ozone (from the Greek *ὀζεῖν*, to emit an odour), was given in 1839 to a smell, by Professor Schönbein, of Basel, the inventor of gun-cotton. Most persons will be acquainted with the peculiar odour which pervades a room in which an electrical machine has been kept in motion. Many will have experienced the sensation of a strange odour filling a house which has been enveloped in discharges from a thunder-cloud. This smell has been compared to that of sulphur from the days of Homer to our own days—

> Then Jove in anger bids his thunders roll,
> And forky lightnings flash from pole to pole.
> Fierce at our heads his deadly bolt he aims,
> Red with uncommon wrath, and wrapt in flames.
> Full on the bark it fell, now high, now low,
> Toss'd and retoss'd, it reeled beneath the blow.
> At once into the main the crew it shook,
> *Sulphureous* odours rose and smouldering smoke.
>
> *Odyssey*, Book XII., 485.

And it was explained by assuming that it was due solely to a peculiar action of electricity on the olfactory organ. Schönbein was the first to detect a material substance in that which had previously been regarded as a sensation, and to prove it to be oxygen in a remarkable condition of energy.

As carbon exists in the state of charcoal and of the diamond; as phosphorus is known in two conditions, the yellow variety, which is poisonous in an extreme degree, and the red kind, which is comparatively inert, and as this double condition has been discovered to exist in many other simple bodies, so oxygen gas is known to possess at least two very distinct states, one of these being the oxygen of the air we breathe under ordinary circumstances, odourless and tasteless, supporting life and acting gently in maintaining all the conditions of animal and vegetable existence, and a comparatively feeble oxidising agent; the other possessing a powerful odour, and a flavour of lobsters, acting as a strong irritant, injurious when in a free state to animals and plants, a very active oxydising agent, and an energetic bleacher.

Ozone forms in the air in extremely minute quantities, nor has chemistry as yet been able to collect it in a pure state. It is also still uncertain whether it is solely formed under the influence of electricity, or whether an intense solar light may have a share in its production. Its quantity increases with the moisture and motion of the atmosphere, and seems to diminish in high temperatures, and when the barometer stands very high. Atmospherical precipitations, rain, snow, and hail, gales and thunderstorms, are favourable to its development. It is the great purifier of the air, the arch-enemy of miasmatic and contagious diseases.

Although throughout the atmospheric ocean the composition of the air is apparently as constant as if it were fixed by the unchanging law of chemical combination, air is simply a *mixture* of oxygen and nitrogen not held together by the force of chemical union.

This purely physical constitution of the air greatly facilitates the innumerable decompositions into which its gases so largely enter. When we remember with what extreme difficulty a true chemical compound of oxygen and nitrogen, such as nitric acid, is decomposed, the dissolution of union only taking place under the force of violent chemical reactions, we well may ask how animals could have breathed at all if the oxygen they inhale had not been floating free and uncombined in the aerial ocean.

Oxygen and nitrogen in the given proportions may be justly regarded as the sole constituents of *atmospheric air*; but the atmosphere would be totally unfitted to fulfil its present functions were there no other gaseous ingredients present in it. Indeed, the salts and dissolved gases of the ocean are not more important to the tribes which people its waters than is the presence of carbonic acid and ammonia in the atmosphere to the terrestrial animals and plants. Possibly, had the atmosphere been created for man alone, and could he have existed on a different description of food to the present, it might have been unnecessary to cast any other ingredients into its composition. But the earth was to be adorned with plants, and these were destined to supply man with a pure, agreeable, and nutritious food. Vegetation cannot exist in a pure atmosphere of oxygen and nitrogen for any length of time, much less thrive, blossom, and produce fruit. A provision was therefore necessary for its wants. Yet here another difficulty presents itself, for the gas which proves most nutritious to vegetation is, at the same time, most deadly in its effects on the animal tribes. This gas is carbonic acid, which, by a most beautiful adjustment, has been mixed with the other gaseous constituents of the pure atmosphere in a proportion so minute as to be altogether without effect upon the human constitution, and yet sufficiently great to satisfy the requirements of the most profuse vegetation.

In no condition of the air is carbonic acid altogether absent, but its quantity is variable. According to the numerous experiments of T. de Saussure, it forms on an average about $\frac{1}{2500}$ of the volume of pure air, but this proportion is very much increased in crowded places, for wherever air is breathed it is continually exhaled.

Carbonic acid is a remarkably heavy gas, so heavy indeed that it may actually be poured like water out of one vessel into another. On account of its weight, which is double that of oxygen, its tendency is to collect and accumulate near the surface of the ground, as may be seen by anyone who will pay a visit to a large brewery. Standing by the side of one of the large fermenting vats, where it is emitted in considerable quantities, and placing himself in such a position that it may be seen against the light, he will perceive trembling, transparent floods of this invisible gas flowing over the top and down the sides of the vessel.

It may well be asked, why carbonic acid, which is constantly pouring into the lighter air in such enormous quantities, apparently disregards the laws of gravitation,[1] and what there is to hinder its falling down and overwhelming the whole human race with its deadly flood? This danger is obviated by the 'power of diffusion,' which causes the heaviest gases to rise up into the air, though less rapidly than the lighter, and to spread to the remotest limits of our atmosphere.

'It would be difficult,' says Dr. Ellis,[2] 'to select a more striking illustration of the wisdom and design displayed in assigning laws to the atmosphere and to gaseous fluids in general than is thus presented to us. The uniformity of the atmosphere is mainly due to the influence of this dispersive force. Diffusion is, as it were, the messenger between man and vegetation, for it conveys to the one the carbonic acid produced and brings back to the other the oxygen restored. By this means is also gradually effected the dispersion of all gases, no matter whether dense or rare. While the heaviest vapours are thus made to rise and spread far and wide, the lighter ones are also caused to descend and intermix with air far more dense than themselves.'

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[1] When Boussingault tells us that in Paris alone more than a hundred millions of cubic feet of carbonic acid are produced every twenty-four hours by processes of combustion and the breathing of men and animals, a faint idea may be formed of the vast production of carbonic acid which is constantly proceeding over the whole surface of the habitable earth.

[2] 'The Chemistry of Creation.' Third edition. London, 1855.

To diffusion we owe the comparative purity of the air in our chambers, which fortunately can never be so thoroughly closed as to cut off all communication with the outer atmosphere; and did not diffusive force lend wings to the balmy air of our fields, it would be deprived of all its scented properties, felt without pleasure, and inhaled without delight.

Accurate investigations have made us acquainted with a fourth ingredient in the atmosphere, which, though extremely minute in quantity, plays an important part in the economy of nature. This ingredient is ammonia—a compound of hydrogen and nitrogen—which streams up from every place where heaps of decomposing animal matter pour out their effluvia. As it rises, it instantly combines with the carbonic acid it meets with in the atmosphere, and being readily absorbed by the aqueous particles floating in the air, descends upon earth along with the dew and rain that moisten and fertilise our fields. It is from this source that our plants are chiefly supplied with their nitrogen, which enters into the composition of the most nutritious vegetable products, such as albumen, gluten, and fruits and seeds generally. These, again, furnish a very essential part of their nourishment to the herbivorous and graminivorous animals, upon which, in their turn, the carnivora depend for their food.

Man, indeed, is an omnivorous creature, but the animals whose flesh he consumes, and which supply his frame with the necessary nitrogen, obtain it exclusively from plants, and these derive it chiefly from the ammonia of the atmosphere. Thus, by an interesting and beautiful series of links, we are ultimately brought to the conclusion that a large portion of our muscles and nerves was once present in the air as gas, the whole amount of which, in upwards of 11,000 cubic feet of air, has been estimated to be about one grain.

The principal means by which atmospheric ammonia is rendered available for the purposes of vegetation, is by its being dissolved in rain-water; but some of our most valuable manures—such as gypsum and burnt clay—of which the agriculturist's experience has taught him the value without revealing the cause, owe some part of their efficacy to the property they possess of absorbing and condensing it from the air, and thus supplying it to the roots of plants.

Besides the above-mentioned gases, which form the permanently elastic envelope of our globe, the atmosphere contains a fluctuating quantity of aqueous vapour which is subject to all the variations of pressure and temperature of the common atmosphere, but through limits far wider, and to changes of physical condition from an invisible gas to the massive weight of the hailstone, which the other, from its permanent gaseous character, never presents.

The aqueous vapour which is diffused through the atmosphere in constantly varying proportions, is as impalpable and transparent as the air itself, and only becomes visible when condensed by a decrease of temperature into the form of fog, mist or cloud. The clearest day, the driest air, is not exempt from it; indeed, in the Alps the purest skies are often most laden with it, the blue deepening with the amount of aqueous vapour in the air.

Though it forms but a small percentage of the total volume of our atmosphere ($\frac{142}{10000}$ according to Dalton), it is of no less paramount importance to the existence of organic life than oxygen itself.

Such are the substances which chemical analysis points out as the constant ingredients of our atmosphere; but this immense aerial ocean contains, moreover, a minute quantity of everything that is capable of assuming a gaseous form, or of remaining suspended in it from its lightness. Here swamps and morasses pour forth hydrogen and carburetted hydrogen; there sulphurous or acid gases issue from craters or volcanic vents. Who can name all the effluvia and organic particles that rise from a great city, or that are carried along on the pinions of the wind; and who can number the various odorous principles which countless plants are constantly imparting to the atmosphere?

Nothing can give a better idea of the extreme divisibility of matter than the diffusion of these inconceivably small particles through the air. Thus one grain of musk placed in a chamber will exhale during several years a very strong smell without any perceptible diminution of weight; and

Haller relates that some papers perfumed with a grain of ambergris still retained a strong odour after forty years.

The presence of particles so minute, and yet capable of making a strong impression on our olfactory nerves, warrants the belief that the atmosphere may possibly contain still undetected substances derived by vaporisation from the earth below, or generated by electricity and chemical changes within the air itself; and which, though unknown and unperceived, may yet play an important part in the economy of nature? The discovery of ozone has revealed the existence of a new and very active atmospherical constituent, of which, not half a century ago, no one had any idea; and it would surely be very bold to assert that, with the detection of ozone, the analysis of the air has been brought to a final end.

Were the innumerable casual substances which are constantly rising from the surface of the earth and mingling with the atmosphere to accumulate in its bosom, there can be no doubt that they would ultimately put an end to the existence of animals and plants. But the atmosphere possesses an admirable self-purifying power. Its oxygen and ozone are constantly decomposing and reducing every noxious gas or organic substance submitted to their influence. Its winds, its aqueous precipitations, and its electricity, accelerate the elimination of all that is extraneously mixed up with it, and thus, age after age, its vast body remains life-sustaining, and unchanged in the midst of perpetual changes.

Having obtained a knowledge of the various gaseous substances which compose the atmosphere, we will now cast a glimpse on their structural arrangement. Like all bodies, whether solid or liquid, each constituent of the vast aerial ocean consists of an aggregate of atoms or molecules.

The elementary atoms of oxygen and nitrogen which constitute, as we have seen, about 99½ per cent. of the atmosphere, may be figured as small spheres scattered thickly in the space which immediately surrounds the earth, and more widely diffused as they recede from its surface. Mixed with these atoms we have others of a totally different character; we have the molecules or atomic groups of carbonic acid, of ammonia, and of aqueous vapour. In these substances diverse atoms have coalesced to form little systems of atoms. The molecule of aqueous vapour, for instance, consists of two atoms of hydrogen united to one of oxygen, and they mingle as little triads among the monads of nitrogen and oxygen, which constitute the great mass of the atmosphere.

The smallness of these elementary monads and molecules is such as to defy the utmost conceivable limits of microscopic power. 'The distances of stellar space,' says Professor Tyndall,[1] 'give us simply a bewildering sense of vastness, without leaving any distinct impression on the mind, and the magnitudes with which we have here to do bewilder us equally in the opposite direction. We are dealing with infinitesimals compared with which the test objects of the microscope are literally immense. The atoms or molecules of the atmosphere are in a constant state of repulsion, in virtue of which they possess the most perfect mobility, and are continually tending to occupy a greater space. But this tendency is counteracted by the earth's attraction, which prevents their rushing away into infinitude, and forces them to encompass the globe, as it were, with an aerial shell. All these atoms or molecules are, moreover, surrounded or embraced by a common medium, the luminiferous ether, which exists within our atmosphere as a second and a finer atmosphere, and must be conceived as infinitely subtle and elastic. It fills stellar space, it makes the universe a whole, and is the medium through which solar light and heat are conveyed to the surface of the earth.'

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[1] 'Fragments of Science,' p. 148.

CHAPTER III.

THE PROPAGATION OF SOUND THROUGH THE AIR.

The Production of Sound—Sonorous or Sounding Bodies—How is the Sensation of Sound produced?—The Wonders of Music—Influence of Sounds on the Human Mind—Cowper—The Forest of Dodona—Aerial Music—The Eolian Lyre—Musical Kites—Measurements of the Rapidity of Sound—Causes which Influence the Intensity of Sound—Its Increase in a colder Temperature and Decrease by the Rarefaction of the Air—Different Ranges of Hearing in different Individuals—Distances at which Sounds can be Heard—Observations made in Balloons—The awful Silence of Night and of the Upper Regions of the Air—Silence of the Arctic Regions—Sounds Imperceptible in a Vacuum.

AN examination of the phenomena of sound leads us into a world of wonders. How is sound produced? how is it transmitted to our ear? how are we able to perceive its infinite gradations and varieties? These are questions, the solution of which cannot fail to interest all those who are in the least desirous to gain some insight into the miracles of nature.

Following sound to its source, we find that in every case the bodies by which it is emitted are in a state of vibratory motion, occasioned by their state of equilibrium having been disturbed either by a shock or friction. The vibrations of these *sonorous* or *sounding* bodies are generally too rapid to be counted or even distinctly seen, yet they may be rendered evident in a variety of ways. If, for instance, a tolerably large bell jar be made to sound by striking it with the finger, and a small ivory ball suspended by a thread be approached to it, the ball will be observed to receive a series of rapid shocks from the sides of the bell, showing that it is in a state of vibration; and in the same manner, if a stretched cord be smartly pulled and let go, its vibrations are apparent to the eye. Or if a plate of metal be fixed horizontally at one end, and sand be strewed over it, when the plate is made to vibrate by briskly moving a violin bow against the edge, the sand becomes violently agitated, which is obviously due to the vibration of the plate.

As in these cases the ball and the sand are seen to move responsively to the vibrations of the sonorous body, we cannot wonder that a substance so mobile, compressible, and elastic as air should be able to transmit it with facility to considerable distances.

Each molecule of air in contact with the sounding body receives an impulsion in the direction of the sound, and returns, having communicated this vibratory motion to the next molecule, and so on until the original impetus of the sound is finally exhausted. The undulation caused by the casting of a stone into still water give us a good idea of the mode in which the waves of sound travel through the air. As from the point where it has been struck the water rises and falls in concentric and constantly widening waves, which, growing weaker as the circle increases, finally cease to be perceptible; so also the waves of sound are propagated through the air in the form of continually increasing spheres until they die away in the distance.

By means of instruments which demonstrate with the utmost accuracy the number of vibrations due to any particular note, we find that the greater the number of vibrations which any instrument performs in a given time, the higher will be the pitch of the note produced. Thus the hum of a gnat is shriller than that of a beetle, because its tiny wings vibrate much more quickly than those of the larger insect, and flap at the inconceivable rate of 15,000 times in a second.

As in the above-cited instance our eye is able to follow the undulations of the agitated water, so also we have been endowed with an organ specially adapted for the perception of the vibratory motions which travel unseen through the air. The aerial waves, on entering the external air, meet a membrane, the so-called *tympanum* or *drum*, which is drawn across the passage at a certain place, and break upon its surface as sea waves do upon the shore. The membrane shakes, and, through a series of small bones and liquids, communicates its tremors to the auditory nerve, which finally transmits them to the brain, where they produce the sensation of sound.

Thus, by a truly admirable chain of physical laws and mechanical contrivances, by a series of wonders beyond all conception, the skill of a consummate artist is enabled to elicit tones of enchanting beauty from inanimate metal or wood, to stir or to soothe the passions of his hearers, to move them to grief or joy, to soft melancholy or to warlike ardour.

How incomplete would be our existence if the atmosphere did not transmit the modulations of sound as distinctly and clearly to our ear as it allows light to speed through its transparent mass. Language and music are carried along upon its elastic waves, and convey instruction and enjoyment to our responsive mind. Our eye might ever so much delight in the aspect of a lovely landscape, the scene would be bereft of half its charms if it spread out before us in deep, uninterrupted silence, if no singing bird ever enlivened it with its notes, or no breeze ever awakened the dormant melodies of the waving cornfield or the rustling grove. The picturesque beauty of the murmuring brook, of the bounding river, or of the foaming cataract, is wonderfully enhanced by the grace or sublimity of their peculiar music; and even the ocean would be far less majestic if it had not voices harmonising with all its humours, now gently rolling over the pebbles of the sunny beach, and now frantically raving against the rock-bound coast. Cowper finely expresses the fascinating power of sound over our feelings in the following well-known lines:—

> There is in souls a sympathy with sounds,
> And as the mind is pitch'd the ear is pleas'd
> With melting airs or martial, brisk or grave;
> Some chord in unison with what we hear
> Is touch'd within us, and the heart replies.
> How soft the music of those village bells,
> Falling at intervals upon the ear
> In cadence sweet, now dying all away,
> Now pealing loud again, and louder still,
> Clear and sonorous, as the gale comes on!
> With easy force it opens all the cells
> Where Mem'ry slept. Wherever I have heard
> A kindred melody, the scene recurs,
> And with it all its pleasures and its pains.

Not only have all the splendours of the universe which light reveals—the glorious firmament, the brilliant sun, or the rainbow's many-coloured arch—been deified by the nations of antiquity; not only have the winds, the viewless messengers of the gods, been personified and worshipped, the sounds also which they elicit as they sweep along have been the founts of religious feelings, the awakeners of devotion in responsive minds. In the holy forest of Dodona, the rustling of the leaves of an ancient oak consecrated to Jupiter was supposed to be the voice of the deity himself. Its sacred language was interpreted by priests to the credulous multitude, who revered it as the most ancient, and, next to that of Delphi, as the most renowned oracle of Greece. Groves of centenary oaks were also the temples 'not reared by human hands,' in which the ancient Germans revered their gods; and when the wind moaned in the branches, they fancied they heard the voice of Wodan, and their hearts were filled with reverential awe.

The inventive genius of man has found the means of eliciting music from the air, and forcing the breeze to please his ear with charming melodies. The Eolian harp is easily made, being nothing more than a long, narrow box of thin deal, with a circle in the middle of the upper side, about one and a-half inch diameter, pierced with small holes. On this side are strings of very fine gut, stretched over bridges at each end, like the bridge of a fiddle, and screwed up or relaxed with screw pins. The strings are all tuned to one and the same note, and the instrument is placed in some current of air where the wind can brush over its strings in freedom. A window with the sash just raised to give the air admission will answer the purpose exactly. Now, when the entering air blows upon these strings with different degrees of force, there will be excited different tones of sound; sometimes the blast brings out all the tones in full concert, sometimes it sinks them to the softest murmurs; it feels for every tone, and by its gradations of strength elicits charming melancholy gradations of sound to 'mortal minstrelsy unknown.'

In central Asia, kites have been invented emitting a musical sound whilst floating in the air. The contrivance, which is very simple and quite worthy of adoption into

England, is described as follows by Major Abbott[1]:—'The kite is a square formed upon two diagonals of light wood, whose extremities are connected by a tight string, forming the sides of the square. Over the whole paper is pasted. A loose string upon the upright diagonal receives the string by which the kite is to be held, and a tail is fastened to its lower extremity. The transverse diagonal or cross-stick is then bent back like a strung bow and fastened by a thread or catgut. Of course every breeze that passes the kite vibrates this tight cord, and the vibrations are communicated to the highly sonorous frame of the kite. And as numbers of these kites are left floating in the air all night, the effect is that of aerial music, monotonous, but full of melancholy interest.

Sound, like all undulatory movements, naturally requires a certain time to pass from one place to another. Thus, if we pay attention to a woodman felling trees at a distance, we see the axe fall in silence, and only hear the sound a moment afterwards; or, when a gun is fired, the flash of light precedes the report. Thunder also is only heard some time after the lightning is seen, although in the cloud both the flash and the sound it occasions are simultaneous.

The velocity of sound has been experimentally determined. During a calm and serene night, a cannon was placed on a hill at Montléry, near Paris, and another on a plateau near Villejuif. The distance of the two cannons was 61,045 feet, and a gun was fired at each station twelve successive times, at intervals of ten minutes. Observers placed near the pieces noted, by means of accurate and delicate watches, the time which elapsed between the appearance of the flash and the hearing the sound at the opposite station; and the mean of the observation gave the number 54·6 seconds. This was exactly the time which the sound required to travel from one station to the other, the time which the light of the flash required to traverse the above distance being too inappreciable to be taken into account. Hence, by a simple calculation, it was found that, at a temperature of 16° Centigrade, sound travels with a velocity of 1,118 feet per second.

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[1] 'Narrative of a Journey from Herat to Khiva.'

Similar direct measurements, made with the utmost accuracy by Moll and Van Beck at Amsterdam in 1823, found the velocity of sound to be 1,098 feet per second in dry air. At the freezing point of water, its velocity increases about two feet per second for every degree Centigrade; so that at 15° Centigrade, which is the ordinary temperature, the velocity of sound is 1,120 feet per second.

EXPERIMENTS ON SOUND.

Though air is the ordinary medium through which sounds are conveyed to our ear, they are also propagated in liquids and solids. When two bodies strike against each other under water, the shock is distinctly heard, and a diver at the bottom of the water can hear the sound of voices on the bank. The earth conducts sound so well that at night, when the ear is applied to the ground, the steps of horses, or any other noise, may be heard at great distances. During a battle, in places where the roar of the artillery dies away in the air, it may still be perceived on resting the ear upon the earth. In ordinary cases, no difference is perceptible in the velocity of sounds, whether strong or weak, grave or acute. Thus, when a tune is played by a band, all its notes are heard at a great distance without any appreciable alteration, which could not be the case if some sounds travelled more rapidly than others. The enjoyment of music, the possibility of understanding a speech at any great distance, entirely depends upon this highly important law; for supposing the grave or acute, the strong or weak tones to be propagated with unequal rapidity, the most eloquent oration or delightful harmony would strike the ear as a mere jumble of sounds. What would then become of our parliamentary debates, our public lectures, our concerts, and our plays?

When sounds are extremely violent, they have, however, been found to travel more rapidly than gentler ones. During artillery practice it was observed by persons stationed at a considerable distance from the guns, that the report of the cannon was heard before the command to fire given by the officer. More recently, Mallet made a series of experiments on the velocity with which sound is propagated in rocks, by observing the times which elapsed before blastings made at Holyhead were heard at a distance. He found that the larger the charge of gunpowder, and therefore the louder the report, the quicker was the transmission.

In consequence of the more rapid propagation of sound in solids than in liquids, sound travelling through the mass of the sonorous body will become sooner audible than the same sound undulating through the air, and thus produce a double report, provided the dimensions of the sonorous body be sufficiently great to render the difference appreciable. Thus it was found by Biot that when a bell was struck by a hammer at one end of an iron tube 3,120 feet long, two sounds were distinctly heard at the other end. The first of these was transmitted by the tube itself, the second by the inclosed air. The interval between the sounds was 2·5 seconds.

To this class of phenomena belongs also the fact that if the ear is held against a rock in which a blasting is being made at a distance, two distinct reports are heard—one transmitted through the rock to the ear, and the other transmitted through the air.

The intensity of sound is influenced by various causes, by the distance of the sonorous body, the amplitude of its vibrations, the proximity of other sonorous bodies, the calmness or motion of the atmosphere, and the density of the air in the place in which it is produced. During a severe frost sounds are heard at a greater distance, because the air is then more dense and more homogeneous. Thus Parry relates that in the Arctic regions, at a temperature of 22° below zero, two persons could easily converse together though more than a mile distant from each other. On high mountains the intensity of sound decreases in a remarkable manner, as it is there propagated through a more rarefied medium. De Saussure observed that the explosion of a pistol on the summit of Mont Blanc produced no greater effect than a common cracker at Geneva. Professor Tyndall repeated the experiment several times on the top of the same mountain, and was mostly surprised at the want of the fullness and sharpness of the sound, which was sensibly feebler and shorter than in the valley, and resembled somewhat the discharge of a cork from a champagne bottle, though much louder.

As the range of seeing is different in different persons, the rays which are obscure to some being still luminous to others, the range of hearing also differs in different individuals. Savart has shown that a good ear can hear a sound produced by fourteen single vibrations per second as well as one produced by 48,000; but there are ears in which the range is much more limited.[1] A sound painfully shrill to one person may thus remain unheard by another. Professor Tyndall relates that he once crossed a Swiss mountain in company with a friend; a donkey was in advance of them, and the dull tramp of the animal was plainly heard by his companion, but to him the sound was almost masked by the shrill chirruping of innumerable insects which thronged the adjacent grass. His friend heard nothing of this; it lay quite beyond his range of hearing.

As the perception of sound thus varies in different individuals, the sense of hearing may possibly range in many animals beyond the limits assigned to our auditory organs. At times when to us the air seems perfectly silent, to them it is still peopled with sounds; and no doubt this wider range of hearing is of great assistance to many animals in avoiding their enemies, or in the pursuit of their prey. The distance at which sounds can be heard depends on their intensity. The report of a volcano at St. Vincent was heard at Demerara, 300 miles off; and the firing at Waterloo was heard at Dover.

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[1] M. Despratz, who has investigated the same subject, disputes Savart's result as to the limits of deep sounds, and holds that no sound is audible that is made by less than thirty-two simple vibrations per second. On the other hand, he maintains that acute sounds are audible up to those corresponding to 73,700 single vibrations per second.

The transmission of sound is facilitated when it passes from a denser to a lighter air. Sound is known to travel better on ascending from a lower to a higher level, because the sonorous waves transmitted from a heavier to a more rarefied air suffer less loss of intensity than when the transmission is in the opposite direction. For this reason the intensity of various sounds emitted at the surface of the earth is carried up to very great heights in the atmosphere.

During his aeronautic travels, M. Flammarion found that the whistle of a locomotive rose to near 10,000 feet, the noise of a railway train to 8,200, and the barking of a dog to 5,900. The shouting of men and women, the crowing of a cock, and the sound of a church-bell, he sometimes heard as high as 5,000 feet. At a height of 3,000 feet the croaking of frogs in a morass appeared to have lost none of its intensity, and even the sharp note of the mole cricket he could easily distinguish at an altitude of 2,500 feet.

It is very different, however, as regards sounds which travel downwards from the balloon to the earth. Whilst the aeronaut can hear distinctly the voice of a man shouting 1,600 feet below him, he himself cannot make himself understood by a person on the ground unless he sinks to within 330 feet of him. Mr. Glaisher[1] found at all times that sounds from the earth were more or less audible, according to the amount of moisture in the air. When in clouds at four miles high, he heard a railway train, but when clouds were far below, no sound ever reached the ear at this elevation. At the height of 10,000 feet he heard the discharge of a gun, and believes that a sound like thunder which struck his ear at the height of 20,000 feet above Birmingham was due to the firing of some guns that were being proved there.

A fog is much more sonorous than dry air, and collects sound with such intensity that whenever, in passing through a cloud, M. Flammarion heard a band playing in a town beneath him, the music always seemed to be close at hand. At the limit at which sound can be perceived through pure air, the interposition of a cloud, though it hides an entire town from sight, is far from weakening sounds; in fact, it may happen that such a cloud enables the aeronaut to detect slight noises which without it he would not have perceived.

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[1] 'Travels in the Air.' Second edition, p. 92.

In populous countries, the noise produced by the manifold activity of man gives rise to a considerable difference in the perception of sounds by day and by night. Millions of sound-waves perpetually crossing each other in every conceivable direction produce a confused and hollow murmur, often like the distant roar of the sea. Tranquillity and silence only prevail during the night, and in solitary places. At night, when almost all animated beings have retired to rest, each individual sound, not being interfered with by others, undulates distinctly to a greater distance, and the ear is then able to distinguish the faintest noises, which become mute during the day. These sounds, breaking through the general silence, are frequently a subject of alarm to nervous and superstitious persons, and have given rise to many a tale of haunted houses and spectral apparitions.

When the aeronaut is sailing through the atmosphere thousands of feet above the level of the sea, his sense of solitude is increased by the extraordinary silence which reigns in the upper regions of the skies. 'Here, and here only,' says Mr. Monck Mason,[1] 'absolute silence can be said to have any existence at all; in every other situation in life, on the summit of the highest mountain, in the depth of the lowest cavern, in the desert and on the sea, in the dead of night and the stern repose of the veriest calm, sound, to a certain extent (however it may escape our faculties), always exists. The vicinity of solid bodies, the resistance of the air, the influence of the changes of temperature upon adjacent matter, nay, the very process of vegetation itself, are so many sources of sound, from which man is never entirely free until the aerial car has snatched him from their influence, and transported him to regions where none such are ever to be found.

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[1] 'Aeronautica.'

Whenever a sound from below does reach his ear in the exalted situation where the confused murmur of innumerable sounds has long since expired, it strikes upon the senses so sharply, simply, strongly, and perspicuously delineated that its casual occurrence becomes even more impressive than the natural stillness of the surrounding medium, extraordinary as that may be. The barking of dogs, the lowing of cattle, the tinkling of the sheep-bell, the exercise of the different instruments of the artificer, the saw, the hammer, and the flail, when at a moderate elevation; the shot of the sportsman, the reiterated percussion of the mill, the discharge of artillery, at a greater distance from the earth, all strike the ear like something new and strange.'

Speaking of the profound tranquillity which reigns in the solitudes of a Novaya Zemlyan landscape, Von Baer remarks that it seems as if the dawn of creation had but just begun, and life were still to be called into existence. The universal silence is but rarely broken by the voice of an animal. But neither the shrill cry of the sea-mew wheeling in the air, nor the rustling of the lemming in the stunted herbage, are able to animate the scene. No sound is heard in calm weather. The rare land birds are silent, as well as the insects which are comparatively still fewer in number. This tranquillity of nature, particularly during serene days, reminds the spectator of the silence of the grave, and the lemmings seem like phantoms as they glide noiselessly from burrow to burrow.

EXPERIMENT ON SOUND.

Sounds can only be heard by the intervention of a medium interposed between the ear and the sonorous body, and vibrating with it. Hence, they are imperceptible in a vacuum, as the following experiment shows:—A small metallic bell, which is continually struck by a small hammer by means of clockwork, or an ordinary musical-box, is placed under the receiver of an air-pump. As long as the receiver is full of air the sound is transmitted, but in proportion as the air is exhausted the sound becomes feebler, and entirely dies away with the exhaustion of the receiver. To ensure the success of the experiment, the bell-work or musical-box must be placed on wadding, for otherwise the vibrations would be transmitted to the air through the plate of the machine.

To judge by this experiment, the luminiferous ether which fills the interstellar spaces, and reveals to us the existence of other worlds, is most probably utterly incapable of transmitting sounds, however intense. Our sun might thus be shivered into countless atoms, or all the stars of the Milky Way clash together, and our ears would remain untouched by the tremendous ruin.

CHAPTER IV.

ECHO.

The Nymph Echo—Sentiments inspired by Echoes—How are Echoes produced—Simple and Multiple Echoes—Remarkable Echoes in Siberia and in Old Calabar River—The Lurlei Echo—The Wetterhorn—Resonance—Its strange Effects—The Gothic Chapel in Paisley—Acoustic Foci—Whispering Galleries—The Ear of Dionysius—The Well in Carisbrook Castle—Effects of Resonance on the various Intensity of Sounds by Day and Night.

AMONG the nymphs with whose graceful forms the lively fancy of the Greeks, ever ready to personify the active and creative powers of Nature, peopled her solitary domains—the mountain and the forest, the grotto and the stream—Echo, the charming enlivener of the silent glen, and of the awful stillness of the woods, holds a conspicuous rank. She was supposed to be the daughter of the Air and the Earth—a parentage against which even the matter-of-fact naturalist of our days can have no objection, as she in reality owes her existence both to the earth which reflects, and to the air which transmits her voice to the ear.

To render herself agreeable to Jupiter, the sprightly nymph once tried by her amusing tattle to divert the attention of Juno, his jealous spouse, as she was about to surprise him while courting one of her attendants. But Juno perceived her intention, and, to punish the officious intermeddler, not only banished her from her presence, but deprived her of speech, only allowing her to repeat the last words of the person who addressed her. Echo, until then so fond of conversing with her comrades, now fled all society, and hid herself in the shady woods, where vain Narcissus, enamoured of his own image which he had seen reflected from a crystal pond, disdained her love. Consumed by grief at his cruel rejection of her tenderness, her body, worn down to a shadow, was changed into stone, and nothing remained of poor Echo but her voice, which only retained the melancholy privilege of repeating the last words of the devious wanderer or of the lover pouring forth his complaints in solitude.

Attenuant vigiles corpus miserabile curæ;
Adducitque cutem macies, et in aëra succus
Corporis omnis abit. Vox tantum atque ossa supersunt.
Vox manet, ossa ferunt lapidis traxisse figuram.
Inde latet silvis, nulloque in monte videtur,
Omnibus auditur; sonus est, qui vivit in illa.

Echo, the nymph whose misfortunes Ovid thus eloquently describes, has long since faded into fable. She no longer wanders disconsolately through the woods, or confides her sorrows to the remote glen or the repercussive rock; but the sounds once ascribed to her still charm the solitudes of Nature, and awaken in the modern poet sentiments of a higher order than those which she inspired in ancient times.

Yes! full surely 'twas the echo,
  Solitary, clear, profound,
Answering to thee, shouting cuckoo,
  Giving to thee sound for sound.

Unsolicited reply
  To a babbling wanderer sent;
Like her ordinary cry,
  Like—but oh! how different!

Hears not also mortal life?
  Hear not we unthinking creatures!
Slaves of folly, love, or strife,
  Voices of two different natures?

Have not we, too? Yes, we have
  Answers, and we know not whence;
Echoes from beyond the grave,
  Recognised intelligence!

Such within ourselves we hear
  Ofttimes, ours though sent from far;
Listen, ponder, hold them dear,
  For of God,—of God they are!—*Wordsworth.*

Echo, the inspirer of poetical fancies, is also a highly interesting natural phenomenon, and charms both the desultory wanderer who loves to listen to her voice, and the earnest investigator whose attention is fixed on tracing appearances to their sources. We have seen, in the preceding chapter, that sound is propagated in air by means of spherical waves alternately condensed and expanded. So long as these waves are not obstructed in their motion, they undulate to a greater and greater distance until they finally die away; but when they meet with an obstacle the same effect is produced as in an elastic ball, which rebounds from the wall against which it is cast. Returning upon themselves, they form new concentric waves, which seem to emanate from a second centre on the other side of the obstacle, and constitute the phenomenon which is called *the reflection of sound.*

An *echo* is the repetition of a sound in the air, caused by its reflection from some obstacle. Thus, if a few words are loudly spoken at a certain distance from a reflecting surface, it sometimes happens that, after a brief interval, the same phrase is heard repeated, as if spoken in the distance by another person; these are the sound-waves which are reflected by the obstacle. To produce an echo there must, however, be a certain distance between the place at which the sound is produced and the reflecting surface.

A very sharp, quick sound can produce an echo when the reflecting surface is fifty-five feet distant; but for articulate sounds, at least double that distance is necessary. A person speaking with a loud voice in front of a reflecting surface, at the distance of 112·5 feet, can only distinguish the last reflected syllable; to hear two, three, or more syllables, the distance must be double or treble, and so on.

Multiple echoes are those which repeat the same sound several times; this is the case when two opposite surfaces (for example, two opposite parallel walls) successively repeat sound. An echo in Woodstock Park repeats seventeen syllables by day and twenty by night; and one on the banks of the Lake del Lupo, above the waterfalls of Terni, repeats fifteen times. But perhaps the most wonderful multiple echo in the world is that described by Wrangell in his 'Siberian Travels.' About two hundred miles from the small town of Kirensk, the mighty Lena forces itself through a defile of precipitous rock walls five hundred feet high. In this place a single pistol shot is repeated more than a hundred times, and with such force as to resemble the rolling fire of a park of artillery. Unfortunately, Echo has in this case chosen so remote a region for the extraordinary display of her powers, that most probably none of my readers will ever have occasion to admire them, or to test the exactness of Wrangell's observations.

The echoes in Old Calabar river, on the coast of Guinea, described by Mr. Hutchinson, are also very remarkable. 'On the morning of the King's dinners, there are always three guns fired to give notification of the day. But listen! a booming sound of ordnance comes over the swamp from Creektown, it rolls and rolls away down the river and over the country by Henshawtown. The gradual diminution of echo at every reverberation at once attracts my listening faculties. A silence of a scarcely appreciable moment ensues. Is it gone? No! further off than I would presume to guess, the roll and the rattle seem making an effort at resuscitation; but they are weaker at every peal, now rallying, now expiring, until I am fixed in the veriest anxiety of attention by the sharp roll of another gun, followed soon after by another. The most remarkable phenomenon of the echo occurs after the third shot is fired. As I strain my attention to hear, I become conscious of the echoes of the three shots being separate and distinct from one another, varying, of course, in intensity by the time which has elapsed between the firing of each. A shot from a rifle, the striking of coopers' hammers on board a ship, have a somewhat similar effect, and the voices of the children singing hymns in the Mission school may be heard re-echoing over the dense bush which abounds in the neighbourhood of Duketown.'[1]

Multiple echoes more or less loud or distinct are of frequent occurrence in mountainous countries or on rocky shores. The cliffs are so many rough, angular reflectors of sound. Some of them send it back directly to the listener, and we have a first echo; some of them send it on to others, from which it is again reflected, forming a second echo.

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[1] 'Impressions of Western Africa.'

Thus, by repeated reflections, successive echoes are sent to the ear, until at length they become so faint as to be inaudible. The sound, as it diminishes in intensity, seems to come from greater and greater distances, as if, like the shy nymph of former days, it was receding deeper and deeper into the mountain solitudes. The old chronicler, Merian, who wrote about the year 1655, mentions the amusement afforded by the echo of the Lurlei rock on the Rhine to the travellers of his day, who strove to awaken it by trumpeting and shouting; and in our days the steamboats generally fire off a cannon as they pass to gratify the passengers with the repeated roar of artillery bursting from the rebellowing mountains. Thus, century after century, this fine echo has been a source of amusement to thousands; and as it replied to the clarions of the Roman legions, it will, no doubt, be admired by many generations yet to come. In Switzerland the Alpine horn is frequently sounded to awaken the slumbering mountain echoes. In the valley of Grindelwald, opposite the colossal Wetterhorn, a skilful artist draws forth at the traveller's approach delightful tones from his rude, unwieldy instrument. A deep silence ensues; but now the walls and clefts of the magnificent mountain return the sound with indescribable beauty. It seems like a choral symphony of supernatural beings, as if the majestic Wetterhorn were chanting his own triumphal song, and calling upon all the world to admire his grandeur. 'Before reaching the summit of the great Scheideck,' says Professor Tyndall, 'I frequently heard the wonderful echoes of the Wetterhorn. The sonorous waves arrived after one, two, three, and more reflections, diminishing gradually in intensity, but increasing in softness, as if in its wanderings from crag to crag the sound had undergone a kind of sifting process, leaving all its grossness behind, and returning in delightful flute notes to the ear.'[1]

When the distance of the reflecting surface is less than 112 feet, the direct and the reflected sound are confounded. They cannot be heard separately, but the sound is strengthened. This is what is called resonance, and its effects are so much the more marked, the more elastic are the surfaces from which the sound is reflected. In uninhabited houses, where there is no furniture, the walls, the flooring, and the ceiling readily vibrate to every sound, while resonance is deadened by tapestry and hangings, which are not elastic. Resonance sometimes produces strange effects in large unfurnished halls. Standing, for instance, on the gallery of the Parisian Exchange, one hears the confused clamour of the excited multitude below; one sees every motion, both of the lips and of the gesticulating hands and arms, but is utterly unable to understand what is said, though often spoken with great vehemence. All these loud voices, with their manifold reflections, produce a chaos of noises, to all appearances as if 'Bedlam were let loose.' In a crowded lecture-room a speech can often be distinctly understood, which becomes unintelligible when it is empty. Professor Tyndall[1] mentions that, having undertaken to hold a course of lectures in the Senate House of the University of Cambridge, he first tried to ascertain how loud he had to speak in order to fill the room, and was very much alarmed when a friend, who was listening on a distant seat, told him he had not been able to follow his words on account of the echoes. When speaking before the assembled audience, however, their presence so effectually damped the sound-waves that the echoes were quite imperceptible, and his voice could be distinctly heard in every part of the Senate House.

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[1] 'The Glaciers of the Alps,' 1861, p. 16.

A vaulted Gothic chapel in Paisley, without pulpit, pew, or any other ornament, is described as having the finest resonance perhaps in the world. When the end door (the only one it has) is shut, the noise is equal to a loud and not very distant clap of thunder. If you strike a single note of music, you have the sound gradually ascending with a great number of repetitions, till it dies away as if at an immense distance, and all the while diffusing itself through the circumambient air. If a good voice sings, or a musical instrument is well played upon, the effect is inexpressibly agreeable. The *deepest* as well as the most *acute* tones are distinctly reverberated, and these in regular intervals of time. When a musical instrument is sounded, it has the effect of a number of instruments of a like size and kind playing in concert. When a number of different instruments in unison sound the same note, a good ear is able to distinguish the variety of sound produced by each. A single instrument sounding a particular note, and then instantly its fifth or any other accordant note, the two sounds can be heard, as it were, running into and uniting with each other in a very agreeable manner. But the effect of a variety of instruments playing in concert is particularly charming.

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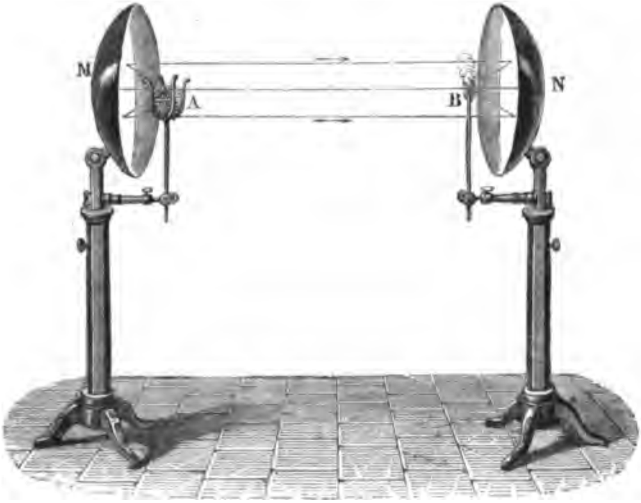
[1] 'On Sound.'



CONJUGATE MIRRORS.

As the laws of the reflection of sound are the same as those of light and heat, curved surfaces produce *acoustic foci* like the luminous and calorific foci produced by concave reflectors. This is easily demonstrated by the well-known experiment of conjugate mirrors,[1] for if a watch be placed in the focus of one of these mirrors, the ear placed in the focus of the second mirror hears the ticking very distinctly, even when the mirrors are at a distance of twelve or thirteen yards. Thus, also, when a person standing under the arch of a bridge speaks with his face turned towards one of the piers, the sound is reproduced near the other pier with such distinctness that a conversation can be kept up in a low tone, which is not heard by anyone standing in the intermediate space. The ticking of a watch can be heard from one end of the church in the Abbey of St. Alban's to the other. An octagon gallery in Gloucester Cathedral carries words spoken in a low voice seventy-five feet across the nave of the church. In the Whispering Gallery of St. Paul's, the faintest sound is carried from one side of the cupola to the other, without being audible in the intermediate spaces. The famous 'Ear of Dionysius,' in the Latomies or Quarries of Syracuse, was a kind of whispering gallery, contrived, it is said, by the tyrant for the purpose of overhearing the conversation of the unsuspecting prisoners whom he had cast into the adjoining dungeons. The story is probably a fable, as it is not mentioned by any of the ancient historians;[1] but so much is certain, that resounding vaults may sometimes become dangerous telltales. Thus Sir John Herschel[2] mentions a cathedral in Sicily where a confessional was placed in such a manner that the whispering of the confessing person was reflected by the curved ceiling, and concentrated in a focus situated in a distant part of the building. This focus was accidentally discovered by a gentleman, who for some time took great pleasure in overhearing the words which were supposed to be exclusively heard by the shriver, and sometimes invited friends to share in his amusement. One day, however, as the story goes, his own wife was in the confessional, and he and his friend thus became the confidants of secrets far from pleasing to one at least of the party.

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[1] In this woodcut two reflectors or conjugate mirrors, M and N, are arranged at a distance of from four to five yards, and so that their axes coincide. In the focus of one of them, A, is placed a small wire basket containing a red-hot iron ball. In the focus of the other is placed B, an inflammable body, such as gun-cotton or phosphorus. The rays emitted from the focus A are first reflected from the mirror M, in a direction parallel to the axes, and, impinging on the other mirror N, are reflected so that they coincide on the focus B. That this is so is proved by the fact that the gun-cotton in this point takes fire, which is not the case if it is above

M. Flammarion remarks that one of the most curious

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or below it. The experiment with the watch demonstrates that sound is reflected in the same manner.

[1] Seume, 'Spaziergang nach Syracus im Jahre 1802.'—a highly interesting work, and still very much read, which can be said of very few books of travels dating seventy years back.

[2] 'Encyclopædia Metropolitana,' Article 'Sound.'

experiments that can be made in a balloon, when passing over a wide sheet of water, consists in observing the beauty of the echo. No other surface is comparable in this respect with that of water, especially for the purity and sonority of the waves of sound that reach the ear. Every syllable that you may happen to address to the limpid surface comes back again with the utmost clearness and distinctness, whilst much louder noises are devoid of echo from the plains and fields.

Resonances are frequently very loud in caverns and rocky clefts, whose walls and hollows reflect the vibrations of the air like so many sounding-boxes. Deep wells are also favourable for their production. In Carisbrook Castle there is a well 210 feet deep and 12 feet broad. The interior is lined with smooth masonry. When a needle is dropped into the well, it is distinctly heard striking upon the water. Sound is also reflected by clouds. When the sky is serene, the report of a cannon in the open field is short and sharp, while a cloud suffices to produce an echo, similar to the rolling of distant thunder.

But even in a perfectly cloudless sky, sound-waves are reflected whenever the sun shines with great intensity, for, owing to the shadows of trees, the evaporation of water, and other causes, not all parts of the earth's surface are equally heated, so that in the atmosphere there are numerous ascending and descending currents of air of different density, which cause the sound-waves to undergo equally numerous reflections whilst passing through them, and consequently weaken their intensity. Humboldt observed that the noise of the great cataracts of the Orinoco at Atures was much stronger at night than during the day; a difference particularly striking in a wilderness where the animals which are silent by day fill the atmosphere in the night with thousands of confused sounds. The explanation of the phenomena must no doubt be sought for in the above-mentioned law. The cataracts are situated in the midst of an extensive savannah, over which numerous rocks are scattered. In the daytime these rocks acquire a temperature far higher than that of the adjoining grass, so that a column of warm and light air ascends from each of them. The sound of the waterfall has consequently to traverse successive strata of air of very unequal density, which make it undergo as many partial reflections, and weaken it as it proceeds. In the night these differences of temperature do not exist, and consequently the sound propagated through a more homogeneous atmosphere reaches the ear without losing its intensity.

The sound of an echo far from the busy haunts of man has frequently a peculiar tone, different from that of the human voice; it strikes us as wanting life, as being what it really is—a mere echo, the dead voice of an inanimate object. Some echoes repeat sound with a tone of laughing mockery; others give it a melancholy expression, which agrees well with the solitude of mountains, or the silence of woods. Like the distant tolling of village bells at eve, it tunes the soul to soft and peaceful reveries. The ancients, with a delicate perception of the harmonies of nature, placed the favourite abodes of the Oreads and forest nymphs in the vicinity of echoes, and believed that the gods themselves delighted to sojourn in those silent and solitary spots where their voice is heard.

CHAPTER V.

THE COLOURS OF THE SKY—DAWN AND TWILIGHT.

What is Light?—The Undulating Theory of Light—The Phenomena of Light analogous to those of Sound—The Luminiferous Ether—The Colours of the Prism—Recomposition of White Light by Newton—Complementary Colours—The Transparency of the Atmosphere—Its vast Importance—Great Transparency of the Air in the Tropics and the Arctic Zone—The Blue Colour of the Sky—Opinions of Leonardo da Vinci and of Goethe on its Cause—Professor Tyndall's Experiments on Vapours—Dawn—Aurora—Ayana, the Hindoo Goddess of Dawn—Twilight—Byron's Description of a beautiful Twilight—Wordsworth—Forbes' Discovery of the Cause of the Colours of Dawn and Twilight—A fine Sunset in the Alps—The Beauties of a Tropical Sky—The successive Changes which take place in the Colouring of the Sky at Twilight and Dawn described by Dr. Von Petzold—Aerial Perspective—We live in the Sky, not under it.

THE aspect of the magnificent optical phenomena of which our atmosphere is the ever-changing scene, necessarily prompts us to investigate the nature of light, the wonderful source from which they are derived.

What is it which thus brilliantly emanates from the sun by day, and from the moon and stars unnumbered during the night, which so splendidly gilds and illumines the canopy of the skies, and, striking on the surface of terrestrial objects, reveals their forms to the eye, and invests them with all the varieties and beauties of colour? This question has no doubt occupied the attention of man ever since his mind first raised itself to thought, but it is only within the present century that it has received a satisfactory solution.

As far as we are acquainted with the natural philosophy of the ancients, their notions on the subject of light were so extremely vague and imperfect that they supposed it to be something emitted by the eye, and for ages the fact remained unknown that it required time to pass through space.

This important discovery was first made in 1676 by Dr. Olaus Römer, a Dane, who, founding his calculations on the attentive observation of the satellites of Jupiter, which, as is well known, alternately appear and disappear behind the planet, proved that the light of the sun requires eight minutes thirteen seconds to reach the earth; or, in other words, travels through space with the inconceivable rapidity of 185,000 miles in a second.

But still the nature of light was hidden in obscurity, and no definitive answer could for a long time be given to the question, whether it was a matter or a mode of motion, an essence or a power that winged its way with such incredible velocity through the immensity of space. According to the emission theory advocated by Newton, La Place, and Biot, light was supposed to consist of extremely minute particles darted out from luminous bodies, and striking against the retina or optic nerve, which hangs like a target at the back of the eye. But this notion, though advocated by men of transcendent genius, has not been able to hold its ground; for Huyghens, Euler, T. Young, and Fresnel have established a more satisfactory creed on the firmest foundations, and modern science no longer doubts that the phenomena of light are completely analogous to those of sound. For both obey the same laws, they are reflected in the same manner, and their interference produces similar results; for as by adding sound to sound silence may be produced, thus also two beams of light may be caused to interfere and effect their mutual extinction. It was this analogy which first suggested that sound and light might be due to a somewhat similar action, and compelled the most profound thinkers to assume that both are motions of oscillation, and, like the propagation of waves in water, take place by a series of vibrations. But while sound is carried along upon the wings of the air, for we have seen that it dies away in a vacuum, light traverses space, quite irrespective of the presence or absence of the atmospheric gases. Its sensation is thus evidently conveyed to our eye by means of a very different medium, as mechanically fitted for the propagation of its wave-motion as is the air for the transmission of the undulation of sounds. This medium, which is called the luminiferous ether, is indeed of so subtle a nature that it entirely escapes our senses; no balance can ever weigh it, no crucible can ever submit it to the test of chemistry, and yet the physical investigator is as convinced of its existence as if it belonged to the world of sense, for its presence fully explains all the phenomena of light, which are utterly inexplicable without it. The luminiferous ether fills all space and penetrates between the molecules of all bodies, but on account of its extreme tenuity it is uninfluenced by gravitation. Taking up the molecular tremors [1] of luminous bodies, it conveys them with inconceivable rapidity to our organs of vision, and reveals to us not only the forms of terrestrial objects, but the existence of stars countless millions of miles distant.

'The ether,' says Professor Tyndall, 'suffers no rupture of continuity at the surface of the eye; the intermolecular spaces of the various humours are filled with it; hence the waves generated by a luminous body can cross these humours and impinge on the optic nerve at the back of the eye. Thus the sensation of light reduces itself to the communication of motion. Up to this point we deal with pure mechanics, but the subsequent translation of the shock of the ethereal waves into consciousness eludes the analysis of science. As an oar dipping into a river generates systems of waves, which, speeding from the centre of disturbance, finally stir the sedges on the bank, so do the vibrating atoms generate in the surrounding ether undulations, which finally stir the filaments of the retina. The motion thus imparted is transmitted with measurable and not very great velocity to the brain, where, by a process which science does not even attempt to unravel, the tremor of the nervous matter is converted into the conscious impression of light.'

The inconceivable rapidity with which light travels through the realms of space forms but part of its wonders. On allowing a pencil of solar light, S A, to pass through a small aperture in the window-shutter of a dark chamber, it tends to form a round and colourless image of the sun at K; but if a flint glass prism, P, arranged horizontally, be interposed in its passage, the beam, on emerging from the prism, becomes refracted towards its base, and produces on a distant screen a vertical band, coloured in all the hues of the rainbow. Thus white light, far from being of a simple and uniform nature, is in reality a compound or mixture of several kinds of light, which, in consequence of their unequal refraction, become dispersed on passing through the prism, and exhibit seven principal colours—violet, indigo, blue, green, yellow, orange, and red—imperceptibly merging the one into the other, through an infinity of intermediate tints.

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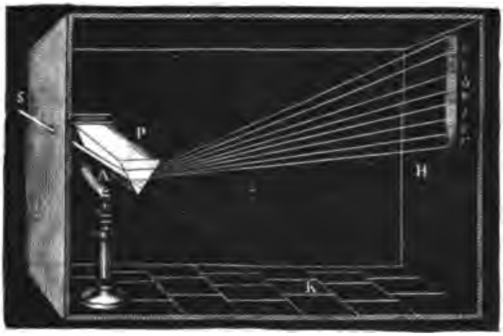
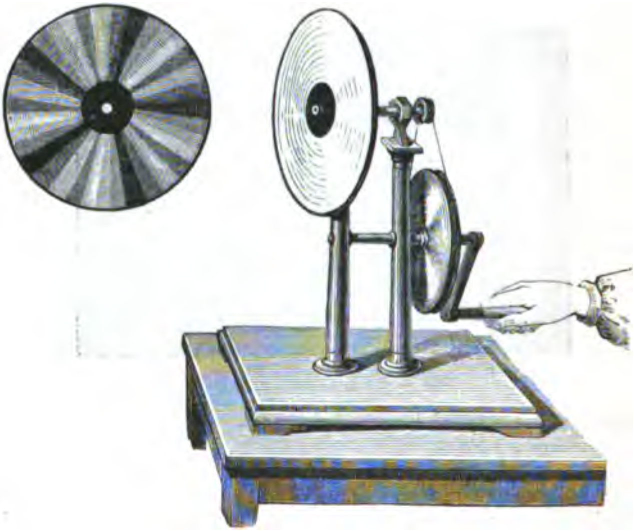
[1] The molecules, or atoms of which all bodies are composed, are conceived to be in a constant state of motion resulting from their attraction and repulsion. They recoil in virtue of the elastic force which opposes actual contact, and in the recoil they are driven too far back. The original attraction then triumphs over the force of recoil, and urges the atoms once more together. Thus, like a pendulum, they oscillate until their motion is imparted to the surrounding ether.



SOLAR SPECTRUM.

The different colours of the spectrum are to the eye what the musical scale is to the ear; they represent notes of different pitch. The vibrations which produce the impression of red are slower, and the etherial waves which they generate are longer than those which produce the impression of violet, while the other colours are excited by waves of some intermediate length. But the short waves and the long waves move with the same rapidity through space, just as short and long waves of sound travel with the same rapidity through air, some striking it oftener in the same time than others. Thus, the shorter waves must follow each other in quicker succession than the longer ones; and it is this difference in the rapidity with which the waves of light impinge upon the retina or optic nerve, which gives rise in consciousness to difference of colour.

Newton, who was the first to decompose white light by the prism, was also the first to recompose it; for by rapidly rotating a large disc on which strips of paper were pasted, representing the relative dimensions and tints of five spectra, the seven colours almost instantaneously striking the retina, their impressions again blended into one, and the disc appeared white.



NEWTON'S DISC.

If in white light any colour be suppressed, a mixture of the remainder is called the complementary colour, for it is the colour needed to complete the sensation of white light. As a mixture of blue and yellow produces a green, green is accordingly the complementary colour to red. In like manner, orange is complementary to blue, and blue to orange.

The relation of bodies to light is as various as their own internal structure or composition. Some are eminently transparent, as air, water, ice; others translucent as snow; others opaque as the metals. But in reality no bodies are quite opaque, for when cut into sufficiently thin leaves they are all more or less translucent.

The different colours of bodies result from the difference of their reflective power for the different kinds of light. Those which reflect all colours in the proportion in which they exist in the spectrum are white, those which reflect none are black. Between these two limits there are infinite tints, according to the greater or less extent to which bodies reflect some colours and absorb others. It is through these innumerable shades and gradations of colour that Nature enchants the eye; for where would be the picturesque beauty of the skies, if they showed us but one unvarying scene, or the charms of the loveliest landscape, if it exhibited but one monotonous colour, or only a few gloomy tints.

To the wonderful transparency of the air we are indebted not only for the free transmission of solar light to our globe, and the consequent awakening and fostering of life on its surface, but also for our knowledge of the existence of other worlds than ours. Stars rolling through space at an incredible distance from our earth send forth their light through the luminous ether which carries it along on its imponderable billows, and, unimpeded by the transparent atmosphere, forms, as it were, the connecting link between our planet and their effulgent orbs. Thus we receive their image as if there were no intervening miles of air, and the grand idea of the infinite beams upon our mind. And yet the atmosphere is not absolutely transparent; for, if so, the apparent vault of heaven would be black, and the partial reflection of light could not take place, which imparts to the sky its rich variety of tints.

As the beams of the vertical sun traverse a less considerable body of air on their passage to the earth than when its orb verges towards the horizon, the imperfect transparency of the air, which is owing to the thin mists floating in the atmosphere, must necessarily cause a proportional decrease in the brilliancy of his rays.

The truth of this observation is proved by daily experience, for while the light of the sun at noon is of a dazzling brightness, we are able to fix our gaze without feeling any inconvenience upon the setting sun. For the same reason, the sky near the horizon shows but a small number of stars even in the clearest night, as the light of these celestial bodies is generally so weakened on its traversing the lower strata of the atmosphere that it is incapable of making any impression upon our optic nerve. As they ascend, they become visible, and, apparently growing out of the vault of heaven, crowd the firmament with their brilliant host.

The transparency of the air increases or diminishes with its dryness or humidity, so that objects placed on the horizon will one day be distinctly seen, and on another hardly visible. In every zone, objects far out on the sea appear less distinct when seen horizontally than when viewed from the top of a mountain, supposing the distances to be equal; for in the first case the intervening atmosphere is uniformly laden with moist emanations, while in the latter the density and dampness of the air diminish, and its transparency at the same time increases as it rises above the level of the water.

The mirror of a lake or of a broad river is far less bright when seen at equal distances from the coast of the Swiss Alps than from the summit of the Cordillera of Mexico or Peru, for the light loses less of its intensity on its passage through the dry tropical atmosphere.

Humboldt remarks[1] that the traveller arriving from the Pacific is astonished at the clearness with which objects thirty-five or forty miles distant are visible from the high plateau of Quito or Antisana. Standing on the summit of the Peak of Teneriffe, the villages, vineyards, and gardens on the coast appear to be remarkably near. In spite of the considerable distance, the houses, the trees, the rigging of the ships, are distinctly seen, and the rich vegetation of the plains shines with the liveliest colours. This remarkable transparency of the atmosphere is due to the dry columns of air which, ascending from the African plains, are rapidly carried by the westerly winds to the Canaries.

Nowhere are the transitions of light and shade more abrupt than in the deserts of the torrid zone, for nowhere is the atmosphere more thoroughly dry and pure. The sun pours a dazzling light on the ground, so that every object stands forth with wonderful clearness, while all that remains in the shade is distinctly traced, and appears like a dark spot in the surrounding glare. Thus the magnificence of tropical landscapes depends in a great measure upon the transparency of the atmosphere, which renders the colours of the plants more vivid, and sets off the beauty of their harmonies and contrasts by the sharp delineation of their contours.

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[1] 'Reise in die Aequinoctial-Gegenden.'

The cold of the Arctic zone, by crystallising and precipitating aqueous vapour, has an effect similar to the dissolving warmth of a torrid climate, and heightens the transparency of the air, by removing the chief cause of its diminution. When the sun sweeps round the pole unobscured by a cloud, the crystal purity of the air is such that objects the most remote may be seen perfectly distinct and clear. A ship's top-gallant mast, at the distance of five or six leagues, may be discerned when just appearing above the horizon with a common perspective glass, and the summits of mountains are visible at a distance of from sixty to a hundred miles. On such sunny days, the strong contrasts of light and shade between the glistening snow and the dark protruding rocks produce a remarkable deception in the apparent distance of the land along a steep mountain coast. When at the distance of twenty miles from Spitzbergen, for instance, it would be easy to induce even a judicious stranger to undertake a passage in a boat to the shore, from a belief that he was within a league of the land. At this distance the portions of rock and patches of snow, as well as the contour of the different hills, are as distinctly marked as similar objects in many other countries not having snow about them would be at a fourth or a fifth part of the distance.

The colours of the sky have, from a very early period, attracted the attention of men curious to investigate the causes of things. Leonardo da Vinci, and many succeeding writers, attributed it to a mixture of light reflected from the matter of the universe with the darkness of the celestial spaces beyond, an opinion which Goethe has revived. In his celebrated 'Treatise on Colours' (Farbenlehre), the illustrious poet, whose comprehensive mind, like that of the great Italian painter, embraced both science and art, explains the colours of the sky by assuming two principles in the universe—light and darkness—and an intermediate stage of turbidity. When the darkness is seen through a turbid medium on which the light falls, the medium appears blue; when the light itself is viewed through such a medium, it is yellow, or orange, or ruby red. Hence the atmosphere sends us blue light or red, according as the darkness of infinite space or the brilliant orb of the sun is regarded through it. In illustration of the action of a turbid medium, Goethe refers, among various other facts, to the blueness of distant mountains, of smoke, and of the lower part of the flame of a candle, which, if looked at with a white surface behind it, entirely disappears.

One of his anecdotes in connexion with this subject is extremely interesting, as it clearly illustrates his theory. The portrait of a high dignitary of the Church, having suffered from long exposure to the dust, was given to a painter to be cleaned. The clergyman was drawn in a black velvet suit, which, to the astonishment of the painter, changed into the colour of blue plush as he passed his sponge over it, and gave its reverend wearer a rather worldly appearance. Goethe was informed of the fact; the experiment was repeated in his presence, and he at once explained it by reference to his theory. The varnish of the picture, when mixed with the water, formed a turbid medium, and the black coat seen through it appeared blue; when the water evaporated, and the turbid medium was withdrawn, the original colour reapppeared.

But the poet's theory, however ingeniously advocated, has not been able to stand the test of strict scientific examination, and we are forced to seek a more satisfactory explanation of the colours of the sky. For this we are indebted to Professor Tyndall's researches, who discovered that wherever extremely attenuated vapours are decomposed or precipitated by the action of solar or the electric light, the first visible action of the light commences in every case with the formation of a blue cloud. The term cloud, however, must not be understood in its ordinary sense; the blue cloud is invisible in ordinary daylight, and, to be seen, must be surrounded by darkness, *it alone* being illuminated by a powerful beam of light. By increasing the quantity of vapour, the precipitated particles grow in size, acquire a white tinge, and, as they thicken, become exactly like real cloud.

We are thus led to the conclusion that extremely attenuated particles of water, the existence of which it is not difficult to conceive in the highest aerial regions, are the reflectors of the blue light which tints the sky.

'The blue colour of the sky,' says the celebrated professor, 'has not the same origin as that of ordinary colouring matter, in which certain portions of the white solar light are extinguished, the colour of the substance being that of the portion which remains. A violet is blue because its molecular texture enables it to quench the green, yellow, and red constituents of white light, and to allow the blue free transmission. A geranium is red because its molecular texture is such as quenches all rays except the red. Such colours are called colours of absorption, but the hue of the sky is not of this character. The blue light of the sky is reflected light; and were there nothing in our atmosphere competent to reflect the solar ray, we should see no blue firmament, but should look into the darkness of infinite space. The reflection of the blue is effected by perfectly colourless particles. Smallness of size alone is requisite to ensure the selection and reflection of this colour. Of all the visual waves emitted by the sun, the shortest and smallest are those which correspond to the colour blue. On such waves, small particles have more power than upon large ones; hence the predominance of blue colour in all light reflected from exceedingly small particles.

To the minute bodies which cause the blue colour of the sky we are also indebted for the diffusion of light. Reflected from all sides, or, as Biot remarks, multiplied by an infinity of repercussions, the solar rays illumine the universal sky, and disperse their light in every direction. Supposing the atmosphere bereft of this reflective power, each point on the surface of the earth could only receive the direct rays of the sun; and the mild brilliancy of the firmament, with all its lovely gradations and plays of colour, would be transformed into monotonous contrasts of profound obscurity and vivid glare.

Planetary space is absolutely black, for it is entirely void of all light-reflecting particles. As the aeronaut ascends in the atmosphere, the aerial strata which separate him from the dark background diminish in thickness, and consequently a deeper tinge is imparted to the blue colour of the sky.

This also accounts for the firmament being more darkly tinted in the zenith, and when seen from the summit of a high mountain, where it is often of an intense Prussian blue. In Coleridge's sublime 'Alpine Hymn' this fact is alluded to in speaking of the 'Sovran Blanc.'

> Around thee and above
> Deep is the air, and dark substantial black,
> An ebon mass. Methinks thou piercest it
> As with a wedge.

In the lower regions the pure blue of the sky is generally veiled by the greater quantity of aqueous particles which mingles with the air. Thus the moist climate of Holland produces a pallid sky, and the damp sea air has a similar effect.

Though agreeable to the eye, particularly after a long period of fog or rain, the aspect of a serene blue sky is far surpassed in beauty by the gorgeous tints of dawn and twilight. A fine sunrise has at all times been a source of religious feelings; and no wonder that when the heathen, after the dark hours of night, saw the sky gradually brightening in the east, and floods of gold inundating the fleecy clouds of morn, he should have paid his orisons to the lovely harbinger of day.

The ancients, who did not as we do consider the phenomena of the atmosphere as the mere effects of physical laws, but endowed them with a living spirit, personified the dawn under the lovely form of Eos or Aurora, a sister of the sun-god Helios or Apollo. Early in the morn, the light-bearing goddess rises from her couch clothed in her saffron robes, and opens the portals of the east with her rosy hand. She is frequently called the rose-fingered by Homer, who constantly consulted nature in the choice of his epithets, and with the fine tact of a great poet always knew how to find an appropriate expression for his thoughts. Drawn by a team of milk-white or rose-coloured horses, she rises in the heavens, preceding the chariot of her brother; or she flies upwards with wide-spreading roseate wings, sprinkling dew upon the earth, and serene and joyous like the new born day.

At her approach the gloomy demons of night conceal themselves in their dismal caves, while all beings that love the light, rejoice and welcome the herald of day.

In ancient India, Ayana, the goddess of the dawn, was likewise an object of religious adoration.

'She shines down upon us like a young bride,' says a fine hymn in the Vedas, or holy book of Brahmins, 'calling all living beings to their daily work. The fire of man was waiting to be kindled, and lo! she created light, dispelling darkness.

'She arose, spreading far and wide, penetrating everywhere, wearing glittering robes; she grew in beauty, the leader of day, golden-coloured, delightful to behold.

'O thou who art a blessing wherever thou appearest, put the evil-minded to flight; be our protectress, illumine us with thy brightest rays, thou flaming dawn.'

If the rising of the sun inspired the first prayers of man, and appeared to his untutored mind as the immediate presence of a Deity, his thoughts were no less forcibly roused to pious contemplation by the gorgeous spectacle of twilight. The mythology of the Greeks personified the splendour of closing day under the form of the beautiful sleeper Endymion; but though in our eyes the bright tints of sunset gradually deepening into shade are a mere optical phenomenon, the ancients felt not more keenly than we do the glories of the magnificent display, behind whose coloured veil we recognise the awful power of an almighty hand. When Strabo or Herodotus, wandering in distant climes, saw the sun disappearing in purple and in gold, their admiration was surely no greater than that of the modern traveller when, far from home, he sees the evening red display its magical effects of light, and no poet of old has drawn a more vivid picture of the beauties of sunset than Byron:—

The moon is up, and yet it is not night—
Sunset divides the sky with her—a sea
Of glory streams along the Alpine height
Of blue Friuli's mountains; Heaven is free
From clouds, but of all colours seems to be
Melted to one vast Iris of the West,
Where the day joins the past eternity;
While, on the other hand, meek Dian's crest
Floats through the azure air—an island of the blest!

A single star is at her side, and reigns
With her o'er half the lovely Heaven; but still
Yon sunny sea heaves brightly, and remains
Roll'd o'er the peak of the far Rhætian hill,
As Day and Night contending were, until
Nature reclaimed her order:—gently flows
The deep-dyed Brenta, where their hues instil
The odorous purple of a new-born rose,
Which streams upon her stream, and glass'd within it glows,

Fill'd with the face of heaven, which, from afar
Comes down upon the waters; all its hues,
From the rich sunset to the rising star,
Their magical variety diffuse:
And now they change; a paler shadow strews
Its mantle o'er the mountains; parting day
Dies like the dolphin, whom each pang imbues
With a new colour as it gasps away,
The last still loveliest, till —'tis gone—and all is grey.

Early dawn, the emblem of infancy, inspires sensations of buoyant hope and elastic activity; but the decline of a beautiful day, the image of a serene old age, is replete with sweet melancholy and placid emotions.

Now o'er the soothed accordant heart we feel
A sympathetic twilight slowly steal,
And ever, as we fondly muse, we find
The soft gloom deepening on the tranquil mind.
Wordsworth.

The accidental (and since then frequently repeated) observation of a column of steam issuing from the safety-valve of a locomotive, led Forbes[1] to the conclusion that the colours of dawn and twilight are not produced by the air itself but by the aqueous particles which are mixed with it. On looking narrowly through the column to the sun, the latter had a deep orange red tinge. This colour, however, appeared only a few feet above the valve from which the steam escaped; at a greater distance, when the steam was more condensed, the phenomenon completely disappeared. The steam cloud, even when moderately thick, was quite opaque, and cast a shadow like a solid body. When more attenuated, it was translucent, but entirely colourless. On these observations, Forbes founded his opinion that the orange colour is due to an intermediate state or to a particular degree of condensation of the steam. As a perfect gas, the latter is quite transparent and colourless; but in its transitional or intermediate state, it gives rise to a colour varying from yellow to intense red, while, when perfectly condensed, it produces fog. It is translucent and colourless when the cloud it forms is thin, and completely opaque when it is thicker. Hence Forbes concluded that the aqueous vapour contained in the atmosphere, as a perfect gas, does not impair its transparency, while in the intermediate state between gas and fog, the aqueous molecules or particles, which we must suppose to be very small, *transmit* the yellow and red rays, and thus give rise to the phenomenon of evening red.

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[1] 'Transactions' of the Roy. Edin. Soc., vol. xiv.

The following experiment confirms the truth of this observation. If a beam of white light be sent through a liquid containing extremely minute particles in a state of suspension, it is found that the blue rays are more copiously reflected by such particles than the red. By dropping, for instance, a very weak alcoholic solution of mastic into a beaker of water, a blue resembling that of the firmament may be produced by *reflected* light. It is best seen when a black cloth is placed behind the glass; but in certain positions this blue liquid appears yellow, and these are the positions when the *transmitted* light reaches the eye. It is evident that this change of colour must necessarily exist, for the blue, being in part removed by more copious reflection, the transmitted light must partake more or less of the character of the complementary colour.

The grand optical phenomena of the firmament, its blue colour on a clear day, and its rich morning and crepuscular tints, can thus be imitated on a small scale, and the effects are so strikingly alike as to suggest a common origin, viz., that the colours of the sky are due to minute particles diffused through the air. The colours of dawn and twilight vary of course with the state of the atmosphere. Not seldom, while the sun is setting, all the shades between yellow and deep red make their appearance, in consequence, no doubt, of the constantly changing direction of the solar beams to our eye, and the number and condition of the aqueous particles they meet with on their way.

The sunset is seldom more beautiful than in stormy weather, when angry clouds sail through a sky resplendent with all the glories of colour. The contrast of their sombre hues heightens the effect of the bright warm tints which suffuse the atmosphere, and their perpetual changes of form and place impart life to the gorgeous spectacle.

One of these magnificent strifes between light and darkness, observed at the station of the Grands Mulets on Mont Blanc, is thus vividly described by Professor Tyndall:—

'I took possession of the flat summit of a prism of rock, where, lying upon my back, I watched the clouds forming and melting and massing themselves together, and tearing themselves, like wool, asunder in the air above. The day waned, and the sunbeams began to assume the colouring due to their passage through the horizontal air. The glorious light, ever deepening in colour, was poured bounteously over crags, and snows, and clouds, and suffused with gold and crimson the atmosphere itself. I had never seen anything grander than the sunset on that day. Clouds, with their central portions densely black, denying all passage to the beams which smote them, floated westward, while the fiery fringes which bordered them were rendered doubly vivid by contrast with the adjacent gloom. The smaller and more attenuated clouds were intensely illumined throughout. Across other inky masses were drawn zigzag bars of radiance which resembled streaks of lightning. The firmament between the clouds faded from a blood red through orange and daffodil into an exquisite green, which spread like a sea of glory through which those magnificent argosies slowly sailed. Some of the clouds were drawn in straight chords across the arch of heaven, these being doubtless the sections of layers of clouds whose horizontal dimensions were hidden from us. The colours around and near the sun himself could not be gazed upon until, as the day declined, they gradually lost their effulgence and became tolerable to the eye. All was calm—but there was a wildness in the sky like that of anger—which boded evil passions on the part of the atmosphere. The sun at length sank behind the hills, but for some time afterwards carmine clouds showed themselves on high, and cast their ruddy hues upon the mountain snows. Duskier and colder waxed the west, colder and sharper the breeze of evening upon the Grands Mulets, and, as twilight deepened towards night, and stars commenced to twinkle through the chilled air, we retired from the scene.'[1]

Twilight and dawn, which so agreeably prolong the day in the higher latitudes, are but of short duration in the tropical regions, where the perpendicular sun rapidly rises above the horizon, and quickly sinks below its verge. The equatorial zone is thus, in a great measure, bereft of those gorgeous displays of colour which the approach and decline of day spread over the northern heavens, but the tropical sky has other beauties to boast of. It is of a deeper blue, and exhibits a greater variety in the formation of its clouds, which, in consequence of a more powerful evaporation, are subject to more rapid transformations, and whose sharp outlines appear on a more vivid background. The daily rains which, in the wet season, cleanse the air of vapours, render the atmosphere wonderfully transparent. The horizon is of the clearest blue, and the stars shine from the pure firmament with that soft planetary light which Humboldt dwells upon with admiration in his 'Aspects of Nature.'

The successive changes which take place in the colouring of the sky, when the sun is about to disappear, are described as follows by Dr. von Petzold:—

'A short time before sunset the lower part of the sky becomes covered with a yellowish white tint, which towards the east passes into a dull purple. This purple zone (the counter twilight) increases in intensity about the moment of sunset, and reaches, according to the condition of the atmosphere, from 6° to 12° above the horizon. As the sun sinks, the ashy grey shadow of the earth rises in the form of a segment, in consequence of which Le Mairan called it the *dark segment.* As soon as the limb of this segment has attained an elevation of more than 1° or 2°, it is tolerably sharply defined. It rapidly pursues its course towards the zenith, seeming to stretch itself in the manner of a dark veil over the counter twilight. As it approaches the upper edge of the latter, its own limit becomes more and more indistinct, until at last it is impossible to recognise it any longer. At this time the sun is from 3° to 4° below the horizon.

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[1] 'The Glaciers of the Alps,' p. 184.

'While this is taking place in the east, a very different spectacle is displayed in the western heavens. The western horizon is coloured at sunset, orange yellow or even red, and this yellowish coloration is defined from the upper blue portion of the sky at an elevation of from 9° to 12° by a very transparent shining whitish zone, which gradually spreads out in a horizontal direction.

'While this *twilight sheen*, as it is called by Brandes, sinks towards the horizon, very delicate purple tints appear at an elevation of about 25°. They increase rapidly in intensity, and form a circular disc with constantly augmenting radius, whose lower part seems to be covered or cut off by the yellow tint.'

This phenomenon, which Petzold calls the first purple light, attains a maximum of intensity when the sun is 4° 20′ below the horizon.

The radius of the disc has at this moment attained a value of about 30°, and its centre is about 15° above the horizon. The centre sinks very quickly, so that the purple light finally contracts to a narrow girdle of dull purple colour, very sharply marking off the yellow portion which, from the form it thus assumes, may be called the *first bright segment*. This limitation retains its sharpness even after the complete disappearance of the purple light, which occurs when the sun is about 6° below the horizon.

While the purple light attains its greatest intensity, westerly objects, which immediately after sunset were quite pale and colourless, appear again illuminated with a tolerably bright rose tint. This illumination is often sufficiently intense to be remarked in narrow town streets, where the sky is scarcely visible. The Alps afford at this time the glorious spectacle of the after-glow. In the vale of Chamouny each of these appearances has its proper name; a distinction is drawn between the *coloration brillante du Mont Blanc*, the *teinte cadavéreuse*; the *coloration seconde*, or *la resurrection*; and lastly the *extinction.*

The moment of complete disappearance of the purple light is accompanied by a remarkable diminution of daylight. For this reason, doubtless, the termination of twilight, popularly so called, that is, of the portion of twilight during which common occupations can be pursued without artificial light, is fixed at about the same moment.

While the first bright segment continues its course towards the horizon, a repetition of the appearances already described is preparing itself in the east. The eastern horizon again displays a faint purple colour or a second *counter twilight*, over which a *second* (but very imperfectly defined) *dark segment* rises up. In the west there appears over the first bright segment a second *twilight sheen*, but not reaching to quite the same elevation as the first; it is separated from the bright segment by a dirty yellowish green stratum. It moves downwards in the same way as the first, and a *second purple light* is gradually developed exactly like the first, except that it is much less intense, and has somewhat more of a reddish tint. It is of course accompanied by a second illumination of favourably situated objects, and thus in the Alps a second after-glow may often be observed.

The second purple light undergoes the same changes as the first, and consequently occasions at last the formation of a second *bright segment.* The course of the phenomena, which are observable in exactly the inverse order on the morning, remains in general the same. The intensity and extent of the individual appearances, however, are very different on different days; nevertheless, twilight always retains its definite character, so that its course can be foreseen from the first.

The progressively changing limits between those parts of the sky which at sunset or at dawn send us chiefly transmitted light, and those which send us chiefly reflected light; the mixture of these two kinds of light, and the fading or extinction of the one while the other still retains its brightness, are probably the cause of the grand and constantly changing phantasmagorias of dawn and twilight. Kämtz has pointed out a relation between their colours and the condition of the sky. When the air was misty, and the atmosphere had in the daytime a whitish appearance, the red was more or less dull, sometimes of a saturated carmine red. After days in which the sky was deep blue, orange and yellow tints predominated. When light clouds were floating in the atmosphere, they were frequently of a very fine red, and then also a more or less grass-green colour was seen in the sky. Probably this phenomenon, which has also been observed over deeply reddened glaciers and ice-fields, is occasioned by the contrast of the neighbouring red clouds. The purple and violet tints probably result from the mixture of the reflected blue colours with the transmitted red.

To the reflection of light caused by thin mists floating in the air, we are indebted for what artists call aerial perspective. On looking from an elevated point at a vast succession of mountain ranges, some near, others skirting the distant horizon, every peak and ridge appears separated from the mountains behind it by a thin blue haze, which plainly points out their various distances. But for this haze all remote objects would seem almost equally distant from the eye, and mountain scenery would lose a great part of its beauty. The haze varies with the temperature and humidity of the atmosphere, and at certain times and places it is almost as blue as the sky itself. In point of fact, it is a piece of more or less perfect sky, for it is produced in the same manner as the firmament itself. 'We live in the sky,' says Professor Tyndall, 'not under it.'

CHAPTER VI.

THE TEMPERATURE OF THE ATMOSPHERE.

Connection between Heat and Light—Luminous and Obscure Rays of the Sun—Sir John Herschel—Ritterian Rays—Importance of Aqueous Vapour as a Heat intercepting Medium—Discovery of this Property by Professor Tyndall—The Thermometer—Fahrenheit, Celsius, Réaumur—How is the Mean Diurnal Temperature of a place Obtained?—The Highest and Lowest Diurnal and Annual Temperatures in Central Europe—Average Coldest and Warmest Days of the Year—Isothermal, Isotheral and Isochimenal Lines—Distinction of Climates according to their Mean Annual Temperatures—Constant, Variable and Extreme Climates—Influence of Height on Temperature—Causes which produce a Decrease of Temperature on Ascending in the Air—Nocturnal Radiation—Its great Refrigerating Power—Used in Bengal for the Formation of Artificial Ice—Influence of the Contraction and Expansion of the Air on its Temperature—Experiments—Mr. Glaisher's Observations on the Decrease of Temperature at Increasing Elevations—Frequent Exceptions to the general rule by rapidly ascending Warm Air Currents—Winter Temperature of high Mountains often higher than in the Valleys—Moderating Influence of the Sea on Temperature—Insular and Continental Climates exemplified in Novaya Zemlya and Port Franklin—Warmest Countries situated partly beyond the Tropics—The Highest and the Lowest Temperatures observed in Various Places—Effects of an Uncommon Heat on Organic Life—How is Man able to Bear the Extremes of Heat and Cold—Experiments of Dr. Fordyce—Cold Wind on the Great Humboldt Glacier—Remarkably Cold Winters and Warm Summers—Warm Winters and Cold Summers—Apparent Anomalies of particular Seasons counterbalance each other—The various Sources of Heat.

AS the manner in which sound is produced and transmitted first suggested that light might be due to a somewhat similar action, thus, in its turn, the discovery of the nature of light led to the conclusion that the heat of a body is caused by an analogous oscillating or vibratory motion of its material particles, the hottest bodies being those in which the vibrations have the greatest velocity and the greatest amplitude. The intimate connexion between heat and light is at once revealed by the circumstance that the beams of the sun which illumine the face of the earth are at the same time the carriers of solar heat which, borne along on the waves of ether, travels with the same inconceivable velocity through the infinite realms of space.

On exposing a thermometer to the various colours which were first unravelled by Sir Isaac Newton's prism, it is found that they are of unequal temperatures; the heating power which is weakest in the violet, gradually rising on passing successively over the other colours, and being greatest in the red. Thus painters, when speaking of blue and green colours as cold, and of red and orange as warm tones, are guided by a correct but unconscious feeling.

The thermic or warmth-imparting action of a solar beam was supposed to be confined to its luminous spectrum, until Sir William Herschel, having placed thermometers in the dark space beyond the red, found that though the light had disappeared, the radiant heat falling on the instrument was more intense than that at any visible part of the spectrum, and thus proved that besides its luminous beams the sun pours forth a multitude of dark or obscure rays, possessing a great calorific power, but entirely unsuited to the purposes of vision.

An experiment so simple may seem to be but of small merit and fully within the scope of a vulgar mind; but, in fact, few men are possessed of that rare and sagacious spirit of enquiry which, turning to account what nobody had ever turned to account before, elucidates great truths by simple means. Whoever should be inclined to think little of Herschel's discovery, may fitly be reminded of the well-known story of Columbus and his egg.

At the violet end of the spectrum the range of the sun's radiations is likewise not limited by that of the eye, but extends into the invisible region beyond, so that the complete spectrum of the sun consists of three distinct parts: first, of ultra red, obscure, but highly calorific rays; secondly, of luminous rays which display the well-known colours of the prism; and thirdly, of ultra violet rays, which, like the ultra red ones, are incompetent to excite vision, but which, unlike the ultra red rays, possess a very feeble heating power. In consequence, however, of their chemical energy, these ultra violet, actinic, or Ritterian rays, as they have been named, after their discoverer Ritter, are of the utmost importance to the organic world.

The waves of heat differ from the waves of light simply as one colour differs from another. As the waves which are red are longer than those which produce yellow, so the waves which produce the obscure heat are longer than those which produce red.

What is true of the sun's obscure rays is also true of calorific rays emanating from any obscure source. We must, in fact, figure a warm body also as having its particles in a state of vibration. When these motions are communicated from particle to particle of the body, the heat is said to be *conducted*; it becomes *radiant* when the particles transmit their vibrations through the surrounding ether. This radiant heat, though obscure, exhibits a deportment exactly similar to light. It may be refracted and reflected and collected in the focus of a mirror. The principle of interference also applies to it, so that by adding heat to heat cold can be produced. In fact, the identity is complete throughout. It was once supposed that the heat of the spectrum was an essence totally distinct from its light, but a profounder knowledge dispels the supposition, and leads us to infer that the selfsame ray falling upon the nerves of feeling excites heat, and falling on the nerves of seeing excites light.

Bodies which readily absorb heat radiate it with the same facility; so that the warmth which the sun imparts to the earth by day, would, after his setting, soon again be lost in space, if an admirable provision had not been made for retarding its escape.

The waves of heat speed from our earth through our atmosphere towards space. In their passage they dash against the atoms of oxygen and nitrogen, and against the molecules of aqueous vapour. Thinly scattered as these latter are, we might naturally think meanly of them as barriers to the waves of heat, and imagine that if these undulations were at all intercepted, it must be by the gases which form the great bulk of the atmosphere, and not by the aqueous vapour which is sparingly diffused among them.

By a series of beautiful experiments, Professor Tyndall has, however, discovered that this small modicum of aqueous vapour intercepts heat with an energy seventy times greater than that of the whole of the air in which it is diffused, and that, comparing a single atom of oxygen or nitrogen with a single atom of aqueous vapour, the action of the latter is 16,000 times that of the former.

Possessed of this extraordinary opacity to the rays of obscure heat, and particularly such rays as are emitted by the earth after it has been warmed by the sun, aqueous vapour stops more than ten per cent. of the terrestrial radiation from the soil of England within ten feet of the surface, a fact which is alone sufficient to show the immense influence which this newly-discovered property of aqueous vapour must exert on the phenomena of meteorology.

'This aqueous vapour,' says Professor Tyndall,[1] 'is a blanket more necessary to the vegetable life of England than clothing is to man. Remove for a single summer night the aqueous vapour from the air which overspreads this country, and you would assuredly destroy every plant capable of being destroyed by a freezing temperature. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the iron grip of frost. The aqueous vapour constitutes a local dam, by which the temperature of the earth's surface is deepened; the dam, however, finally overflows, and we give to space all that we receive from the sun. It is the absence of this screen, and the consequent copious waste of heat, that causes mountains to be so much chilled when the sun is withdrawn. Its absence in Central Asia renders the winter there almost unendurable; in Sahara the dryness of the air is sometimes such that though during the day "the soil is fire and the wind is flame," the chill at night is painful to bear. In Australia also, the thermometric range is enormous, on account of the absence of this qualifying agent. A clear day and a dry day, moreover, are very different things. The atmosphere may possess great visual clearness while it is charged with aqueous vapour, and on such occasions great chilling cannot occur by terrestrial radiation. Sir John Leslie and others have been perplexed by the varying indications of their instruments on days equally bright; but all these anomalies are completely accounted for by reference to this newly-discovered property of transparent aqueous vapour. Its presence would check the earth's loss; its absence, without sensibly altering the transparency of the air, would open wide a door for the escape of the earth's heat into infinitude.'

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[1] 'Proceedings' of the Royal Institution, Jan. 23, 1863.

The ever-varying changes of temperature to which the air is subject have so great an influence both on meteorological phenomena in general, and on the occupations of daily life, while the knowledge of them is so scientifically interesting and so practically useful, that ever since the thermometer was invented, no physical instrument has been oftener and more universally consulted. We all know that in our ordinary thermometers the expansion or contraction of a column of mercury or alcohol enclosed in a graduated tube indicates the fluctuations of temperature which are constantly taking place in the air.

The mercurial thermometer is the most extensively used. It consists of a capillary glass tube, at the end of which is blown the bulb, a cylinder or spherical reservoir. Both the bulb and a part of the stem are filled with mercury, and the expansion measured by a scale graduated either on the stem itself or on a frame to which it is attached.

There are three modes of division of the thermometric scale. On the Continent, and more especially in France, the range from the freezing to the boiling point of water is divided into 100 parts, and this division is called the Centigrade or the Celsius scale, after the Swedish philosopher who first proposed it. Temperatures below 0° C., or the freezing point of water, are designated by the minus sign; thus $-15°$ C. signifies fifteen degrees of the Centigrade scale below zero.

In Réaumur's scale, the fixed points are the same as in the Centigrade scale, but the distance between is divided into 80 degrees instead of into 100. Eighty degrees Réaumur are thus equal to 100° C., and one degree Réaumur is equal to $\frac{5}{4}$ths of a degree Centigrade. Consequently, to convert any number of Réaumur degrees into Centigrade degrees, they have merely to be multiplied by five and then divided by four.

The thermometric scale invented by Fahrenheit in 1714 is still much used in England, also in Holland and North America. The higher fixed point is like that of the preceding scales—the temperature of boiling water; but the null point or zero is the temperature obtained by mixing sal ammonia and snow, and the interval between the two points is divided into 212 degrees. The zero was selected because the temperature was the lowest then known, and was thought to represent absolute cold.

When Fahrenheit's thermometer is placed in melting ice, and consequently indicates the temperature of freezing water, it stands at 32 degrees; and therefore 100 degrees on the Centigrade scale are equal to 180 degrees on the Fahrenheit scale, and thus one degree Centigrade is equal to nine-fifths of a degree Fahrenheit; and inversely, one degree Fahrenheit is equal to five-ninths of a degree Centigrade. If it be required to convert a certain number of Fahrenheit degrees into Centigrade degrees, the number 32 must first be subtracted in order that the degrees may count from the same part of the scale. When, for instance, Fahrenheit's thermometer stands at +100, we convert this number into Centigrade degrees by first subtracting 32, then multiplying the remaining 68 by five, and dividing the product by nine, which gives us $+37\frac{7}{9}^\circ$ C. But when Fahrenheit stands below zero, then 32 degrees have to be added in order to find the corresponding Centigrade temperature. There can be no doubt that the Centigrade scale is by far the most convenient, and that its universal adoption would save much calculation and trouble; but as most of my readers are probably more accustomed to Fahrenheit, I have adopted his scale throughout this work.

As mercury freezes at -40°, the alcohol thermometer is especially used for low temperatures, for it does not solidify at the greatest known cold.

To obtain the exact mean diurnal temperature of a place, it seems necessary that at least twenty-four hourly observations of the thermometer should be added together and then divided by twenty-four. But as it is extremely difficult and tiresome to continue such minute observations for any length of time, methods have been devised for making a smaller number of daily thermometrical observations answer the same purpose.

Humboldt first showed that a very close approximation to the mean temperature is obtained by taking the mean of the maxima and minima temperatures of the day and of the night, which are determined by means of self-indicating maximum and minimum thermometers. Another method is to make three or four daily readings of the thermometer at regular intervals, as, for instance, eight o'clock in the morning, four o'clock in the afternoon, and midnight; or four and ten in the morning, and four and ten in the afternoon and evening, and then to take the mean of these three or four observations.

The temperature of a month is the mean of those of thirty days, and the temperature of the year is the mean of those of twelve months. Finally, the temperature of a place is the mean of its annual temperature for a great series of years.

Reckoning one day with the other, the lowest temperature in central Europe is generally before the rising of the sun, the highest in summer towards three o'clock in the afternoon, and in winter between one and two. One of the mean temperatures is between eight and nine in the evening, the other between eight and ten in the morning.

On comparing thermometrical observations made during a series of years in many different places in the northern temperate zone, we find that in general the temperature is lowest about the middle of January. From that time it rises, at first slower, then more rapidly in April and May, and then again more slowly until it attains its maximum towards the end of July. A slow decrease now begins, which is accelerated in September and October, and continues by slow degrees till January.

According to Kämtz, January 14 is on an average the coldest, and July 26 the warmest day of the year; while the mean temperature of the year coincides with that of April 24 and October 21.

It is almost superfluous to remark that in order to make accurate thermometrical observations, great precautions must be taken in the placing of the instrument. A very exact, but somewhat slowly-moving, thermometer should be hung up in the shade, particularly on the north side of a building at some distance from the ground, a foot from the wall, and far from all objects which might influence it by their radiation. The wind, however strong, must have no influence on the indications of the instrument. Whenever the mercurial column of a thermometer exposed to the wind is lower than that of another placed beyond its immediate reach, there can be no doubt that external calorific influences have not been entirely removed from the latter.

If the temperature of a place entirely depended upon its latitude, we should find a gradual decrease of warmth from the tropics to the temperate and arctic zones, in consequence of the increasing obliquity of the solar rays and their progressively decreasing power. This loss is, however, in summer partially compensated in the temperate and arctic zones by the length of the days; and, moreover, the temperature of a place is modified by so many other causes, such as its altitude, the direction of the winds, the vicinity of the sea, &c., that places of the same annual temperature are not seldom ten or more degrees of latitude apart from each other.

When on a map all the points of which the temperature is known to be the same are joined, curves are obtained to which Humboldt first directed attention, and which he called isothermal lines. We know, indeed, as yet, the temperature of too small a number of places to be able to draw a complete net of isotherms over the globe; but in the northern hemisphere at least, sufficient observations have been collected to indicate their chief directions, and to give some idea of their remarkable deviations from the lines of latitude. A distinction is made between isothermal lines, isotheral lines, and isochimenal lines, when the mean general, the mean summer, and the mean winter temperatures are respectively constant.

Some writers distinguish seven classes of climates, according to their mean annual temperature:—a hot climate, from 85° to 77°, a warm climate from 77° to 68°, a mild climate from 68° to 59°, a temperate climate from 59° to 50°, a cold climate from 50° to 41°, a very cold climate from 41° to 32°, and an arctic climate where the temperature is below the freezing point of water.

Climates are also classed as constant, when the difference of temperature between the various seasons does not exceed 10° or 14°, variable climates where it amounts to from 27° to 36°, and extreme climates where the difference is greater than 54°. The climate of Madeira, for instance, is constant, that of England variable, and that of Central Siberia extreme.

But the temperature of a place is by no means the only meteorological condition which influences its climate; for this depends also upon the humidity or dryness of the air, the direction of the winds, the quantity and frequency of the rains, and many other local causes.

The height of a place has a much more considerable influence on its temperature than the latitude in which it is situated. The aeronaut who ascends to a considerable altitude on a warm day meets with a chilling cold in the upper regions of the atmosphere; and on the Peruvian Andes the traveller may in the morning leave the snow-decked Puna hut, and before sunset pluck bananas on the skirts of the primeval forest. Mere latitude interposes a wide barrier between summer and winter, but high mountains bring them into close proximity.

The decrease of temperature which we experience on ascending in the atmosphere results from various causes. The greater rarefaction of the air necessarily diminishes its absorbing power; besides which the air is at a greater distance from the ground which heats it by contact, and finally there is the great diathermanous power of dry air. The quantity of aqueous vapour in the atmosphere diminishes as we ascend; and thus the vapour-screen which so effectually tempers the climate of England is more or less withdrawn from above the mountains, whose heat consequently gushes freely into space The wanderer on a high mountain feels the sun glow at noonday more ardently than in the plains,[1] but towards evening the rapid dissipation of the warmth it imparted to the ground is shown by the quick descent of the thermometer.

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[1] By a series of observations made by Soret at Geneva and on the summit of Mont Blanc, he found the intensity of the solar heat at the top of the mountain to be $\frac{6}{5}$ths of that at Geneva.

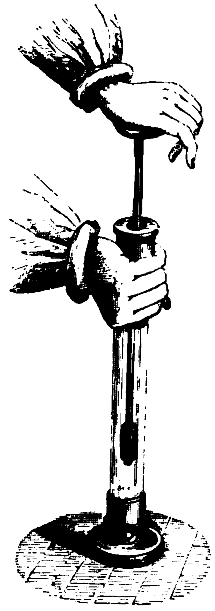
The refrigerating power of nocturnal radiation, which so sensibly affects the temperature of high mountains, is indeed so great that it is able to congeal water even in a tropical climate. This effect is made use of in Bengal for the formation of artificial ice. Shallow pits are dug which are partially filled with straw, and on the straw flat pans containing water which had been boiled is exposed to the clear firmament. The water is a powerful radiant, and sends off its heat copiously into space. The heat thus lost cannot be supplied from the earth, this source being cut off by the non-conducting straw. Before sunrise a cake of ice is formed in each vessel. To produce the ice in abundance the atmosphere must, however, not only be clear but it must be comparatively free from aqueous vapour. When the straw in which the pans are laid becomes wetted with dew, it must be changed for dry straw, as the vapour rising from the wet straw, and overspreading the pans like a screen, would check the chill and retard the congelation.

Another circumstance likewise contributes to the decrease of warmth in greater altitudes. In consequence of the diminution of pressure, the air expands as it ascends, and thus part of its caloric becomes latent. On the other hand, by a renewed compression, the same quantity of heat is again liberated or rendered sensible, which had lost its activity through expansion. Fancy a warm current of air striking against a steep mountain wall. As it is forced upwards, it expands, and its temperature diminishes accordingly. But supposing it to rush downwards along a valley after it has reached the summit of the mountain, a proportional increase of its temperature must take place on its again descending to a lower level.

The following experiments show the immense influence of contraction and expansion on the temperature of the air, and give us a fair idea of its meteorological importance:—

On driving down an hermetically fitting piston into a pneumatic syringe or strong cylinder of glass, accurately bored and quite smooth within, the sudden compression of the air enclosed in the cylinder generates so much heat that it may be made to ignite tinder.

Sir Humphry Davy, in his 'Chemical Philosophy,' mentions a machine in the mines of Schemnitz, in Hungary, in which air was compressed by a column of water 260 feet high. When a stop-cock was opened, so as to allow the highly condensed air to escape, a degree of cold was produced by its sudden expansion which condensed the aqueous vapour diffused in the air into a shower of snow, while the pipe from which the air issued became fringed with icicles.



PNEUMATIC SYRINGE.

The chill caused by expansion has even been turned to a practical account, as, for instance, in Kirk's machine, for the manufacture of ice. The heat developed by the compression of air is removed by a current of cold water; the vessel containing the compressed air being placed in brine, the air is allowed to expand; in so doing, it cools the brine so considerably as to freeze water contained in vessels placed in the brine. It is stated that by this means a ton of coals (used in working a steam-engine by which the compression is effected) can produce a ton of ice. The agency of a heat-generating substance is thus ingeniously employed for the production of an intense degree of cold.

Recent observations show that the formerly generally admitted theory of a regular diminution of temperature of one degree Fahrenheit for every increase of 300 feet of elevation, is now no longer tenable, for even with a clear sky, the most favourable for establishing a mean, the decrease of temperature is very far from constant. We now know that within 100 feet near to the earth the thermometer may fall several degrees during the mid-hours of the day, and, as is generally the case, increases as much during the mid-hours of the night.

Mr. Glaisher found the decline of temperature near the earth to be different according to the more or less cloudy state of the sky, being more rapid where the latter was clear than when cloudy. The general result of all the mid-day experiments made during his various balloon ascents was as follows:—

The change from the ground to 1,000 feet high was 4° 5′ with a cloudy sky, and 6° 2′ with a clear sky. At 10,000 feet high it was 2° 2′ with cloudy sky, and 2° 0′ with a clear sky. At 20,000 feet high the decline of temperature was 1° 1′ with a cloudy sky, and 1° 2′ with a clear sky. At 30,000 feet high the whole decline of temperature was found to be 62°.

Within the first thousand feet, the average space passed through for 1° was 223 feet with a cloudy sky, and 162 feet with a clear sky. At 10,000 feet the space passed through for a like decline was 455 for the former, and 417 for the latter; and above 20,000 feet high the space with both states of the sky was 1,000 feet nearly for a decline of one degree.

Not seldom, however, the temperature of the air instead of declining is found to increase at a greater elevation, for aeronauts often meet with warmer air currents as they rise to greater heights, and warm and rapidly ascending air currents raise the temperature on the highest mountains. On the Antisana, at a height of 18,000 feet, Humboldt found a temperature of 75°, and La Billardière's thermometer marked 66° near the crater of the Peak of Teneriffe. As the temperature in the roads of Santa Cruz was at the same time 83°, the difference was thus only 17° instead of 36°, as it would have been according to the law of progressive decrease.

In mountainous countries the temperature of the air not seldom rises during the winter on ascending to a greater height. At a lower level the pasture grounds and fir forests may then be seen covered with hoar frost, while higher up they are completely green. The boundary of these two zones varies in the Carinthian Alps, between 2,800 and 5,000 feet, and is generally very striking, from the difference of colour, which traces a distinct line of demarcation between them. The phenomenon only takes place in calm serene weather, and then the deep valleys are not seldom seen covered in the morning with a thick fog, which, however, disappears towards noon with the deposition of a copious hoar frost, while the sunny mountain tops and the high slopes are clothed with verdure.

The cause of a phenomenon so much at variance with the general rule is that the higher regions are often warmed by the sun while dense mists obscure the valleys. Below, the cold air forming, as it were, an atmospherical lake, enclosed on all sides by high rock walls, frequently remains stagnant; while above, the interchange of temperature between cold and warm currents more readily takes place. The formation of hoar frost in the valleys disengages, moreover, a certain quantity of heat, which has a tendency to rise, while colder air-streams flow downwards along the mountain slopes. In many deep valleys the sun never shines at all during the whole winter or only during a small part of the day, while at a higher elevation his calorific beams impart warmth to the ground. Frequently also warm air currents are sailing along the mountain tops while the air remains cold in the valleys.

The observations that have been made at the various meteorological stations established in Switzerland, at elevations of from 6,000 to 7,000 feet, show that the lowest winter temperatures at considerable heights do not much exceed those which reign at a much lower level.

The relative mildness of the Alpine winter is particularly conspicuous on isolated peaks exposed to the action of the sun, and to the free contact of warm winds. Thus on comparing the summit of the Righi (5,541 German feet) with Bevers (5,264 German feet,) which is situated at the bottom of the valley of the Upper Engadin, we find that their temperatures in January, taken from a mean of six winters (1864–69) were respectively + 3° 5′ and − 14° F., and that the greatest cold observed during the same period was − 7° (February 1865) on the Righi, and − 23° 4′ (January 1869) at Bevers.

Extensive sheets of water have a tendency to counteract both excessive cold and excessive heat. For water requires four times as much caloric as the solid earth in order to be raised to the same temperature, and, moreover, the rays of the sun penetrate to a great depth in the water before they are completely absorbed or transformed into perceptible heat. They consequently diffuse their caloric over a greater mass, an effect which is still more increased by the mobility of water, by currents and wave motion. The evaporation of water, which increases with the warmth of the atmosphere, likewise tends to cool the air, as a great quantity of caloric becomes latent by its being changed into vapour, and consequently no longer contributes to raise the temperature of the air.

When the cold increases, water, on the contrary, is generally warmer than the solid earth. Its surface, indeed, radiates warmth into space as easily as the ground, but as it cools it becomes heavier, and sinks to make room for warmer water rising from below, and thus refrigeration is retarded. At the same time, there is less loss of heat from evaporation than in warm weather. Thus the sea mitigates both solar heat and nocturnal radiation, and for this reason islands and coasts in general have a more constant climate than the interior of continents, where, in consequence of the more rapid warming and cooling of the ground, the different seasons and diurnal periods undergo much greater changes of temperature. Even in the tropical zone, the opposite influences of the sea and of the dry land on the temperature of the air are very striking, but this is still more the case in the polar regions. In the antarctic zone, where the sea predominates by far over the dry land, the icy waters oppose so obstinate a resistance to the calorific power of the sun, that an eternal winter reigns on the islands of that desolate ocean, while in the arctic zone the large continental masses of Siberia and North America are so thoroughly warmed by a sun which for months together stands over the horizon, that the summer ripens corn in the same countries where mercury freezes in winter.

The influence of the insular or continental character of a locality is strikingly exemplified by the contrast between the climates of Novaya Zemlya and the interior of arctic America, both so rigorous, yet so unlike.

	Novaya Zemlya.	Fort Franklin.
Mean temperature	16° F.	17° 6′ F.
,, of 3 summer months . .	36° 65	50° 4′
,, of 3 winter months . .	3°	17° 8′

The climate of Novaya Zemlya is, therefore, one of the most dreary in the known world; the summer temperature scarcely rising above the freezing point of water, whilst Arctic America, though far colder in winter, enjoys a European warmth for at least some weeks. The warmest month at Novaya Zemlya (August) has a temperature 39° less than that of January in Shetland. The warmest month at Port Franklin reaches 52°, or almost that of Lerwick in Shetland. The extremes are not less surprisingly different.

Extreme heat	at N. Zemlya,	49° F.;	at Fort Franklin,	80° F.
„ cold	„	53°	„ „	58°
Range . .		102°		138°

Enormous as both these ranges are, we cannot but observe that the Novaya Zemlyan extreme warmth does not approach within 30° of the American one, and yet the mean annual temperature of both stations is nearly alike. The influence of elevation, and of the distribution of land and water, thus evidently shows us that the mere latitude of a place can by no means give us an accurate measure of its climate with regard to temperature. The very warmest countries of the northern hemisphere, for instance, are situated not immediately under the line, but far to the north, partly even beyond the tropic of Cancer. They comprise Nubia, South Arabia, South-west Persia, and a great part of the Red Sea and the Persian Gulf. Here the average warmth of July attains the enormous height of 90·5°. 'Here,' say the Arabs, who love a figurative mode of speech, 'the earth is of fire and the wind of flame.' Not quite so hot, but still surpassing all the countries under the line in aestival heat, are North India and the Eastern Sahara, which are likewise mostly situated beyond the tropical zone. In America also we find the hottest summers (81·5°) in the Mexican Gulf, the Caribbean Sea, and the adjoining coast lands, which are mostly situated far to the north of the equator, or even within the temperate zone.

On the other hand, it has been found that in the Polar regions the greatest cold does not reign in the extreme north, but even to the south of the arctic circle.

The winters in the interior of Siberia and of the Hudson's Bay territories are far more severe than on the coasts of

Spitzbergen, and the explorers of the 'Polaris' met with a milder climate as they penetrated through Smith's Sound into the unknown deserts beyond.

In the following table the reader will find a statement of the mean temperatures of fifty places, situated in various parts of the world, and all within 600 feet above the level of the sea, which will show him at once how powerfully the climate of a locality is influenced by circumstances independent of its geographical position as to latitude.

Places	Latitude	Mean Annual Temperature	Mean Summer Temperature	Mean Winter Temperature
Winter Harbour, Melville Island . .	74°·45	19°	37°·5	28°
North Cape . . .	71·10	32	43·2	23·5
Petersburg . . .	59·56	39	62	17
Edinburgh . . .	55·58	47	58	38
Moscow	55·47	38	62·5	13
Isle of Man . . .	54·12	49·8	59·1	42
Hamburg . . .	53·33	48	66·2	33
Manchester . . .	53·30	48	58·5	37·2
Dublin	53·21	49·2	59·7	39·4
Berlin	52·31	48·3	64	30·7
Oxford	51·46	49	60	38·3
London	51·31	49·5	62	38
Brussels . . .	50·50	52	66·5	37
Paris	48·50	51·7	64·5	38·7
Milan	45·28	56	73	36·2
Bordeaux . . .	44·50	56·5	71	42
Marseilles . . .	43·18	54	73	45·2
Hobart Town, Van Diemen's Land . .	42·53 S.	52·3	63	42·2
Rome	41·54	60	78·2	47
New York . . .	40·40	54	79	30
Philadelphia . . .	39·56	53·4	74	32·2
Peking	39·54	55	82·8	26·3
Cincinnati . . .	39·6	55·5	73·2	31
Washington . . .	38·53	56·4	76·4	37·6
Lisbon	38·43	61·6	71	52·7
Palermo . . .	38·7	62·4	72	52·4
Algiers	36·48	70	80·2	55·6
Canca, Creta . . .	35·29	64·6	77·3	53·9
Cape Town . . .	33·55 S.	66·5	74·5	58·5
Funchal . . .	32·38	67.5	71·6	63·6
Natchez, Mississippi .	31·28	65	79·4	48·9
Cairo	30·3	72	85	58·3
St. Augustin, Florida .	29·50	72·3	83	59·6
Santa Cruz, Teneriffe .	28·28	71	76·5	64·8
Abuschur . . .	28·15	77	92	61·8
Havannah . . .	23·9	78	83·4	71·5
Macao	23·8	75·2	84·6	63·5
Calcutta . . .	22·35	79·3	83	70
Hawaii	19·30	75·5	78·4	71
Vera Cruz . . .	19·12 N.	77	82	71

Places	Latitude	Mean Annual Temperature	Mean Summer Temperature	Mean Winter Temperature
	°	°	°	°
Bombay	18·58 N.	79·8	82·7	73·5
St. Domingo	18·15	81·3	85	77·7
Cobbe, Darfur	14·11	81	87·4	69
Madras	13·5	82	86·2	77
Kouka, Borneo	12·11	83·5	84·8	76·6
Cumana	10·27	82	84	80
Trincomalee, Ceylon	8·32	81·8	83	78·3
Sierra Leone	8·30	81	83·5	79
Batavia	6·12 S.	78·5	79·8	78
Surinam	5·38 N.	78	78	77·6

The highest and the lowest temperatures that have been observed in various places often exceed by far their mean temperatures. Thus the thermometer has been known to rise to 84° in the shade at Penzance, to 90° at Edinburgh, and to 96° near London. One hundred and seven degrees have been noticed at Palermo, 105° at Athens, 102° at Lisbon; and, strange to say, Germany, though situated so much farther to the north, has sometimes seen the thermometer rise to a height but very rarely exceeded in Southern Europe—103° at Stuttgart, a town enclosed on all sides by hills covered with vineyards, 102½° at Berlin, and 102° at Dresden.

In the tropical countries we of course meet with instances of heat far exceeding the above-mentioned temperatures—at Benares 112°, in the plain of Peshawur 113°, at Seringapatam 115°. How delightful to a European must have been the day at Bagdad, when the thermometer stood at 120° in the shade; or at Mascate, when in June 1821 it rose to 122°, and fell at midnight to the comparative coolness of 104°.

During the French expedition to Egypt under Bonaparte, the thermometer once rose to 126·5° at Suez; but even Suez has been surpassed by Murzuk (25·54° N. lat.), where it has been known to stand at 133°. Where the thermometer does not hang freely in the air, and is not protected against the rays of caloric reflected from the ground or from neighbouring walls, it indicates still higher temperatures even in Europe. Thus Pouillet noted 149° in a small garden in Paris, where all the above-mentioned precautions had been purposely neglected.

The effects of an uncommon heat on organic life are admirably described by Humboldt in his 'Aspects of Nature.' During a very hot day the great naturalist was staying near the rapids of the Orinoco. A thermometer suspended in the shade several inches above the granitic mass of tower-like rocks through which the river forces its tumultuous passage, stood at 122°. The contours of all distant objects appeared to be in a wave-like motion—a consequence of mirage. Not a breath of air disturbed the fine sand which covered the ground. The sun was in the zenith, and the mass of light which it threw upon the stream rendered still more apparent the hazy redness which veiled the distant prospect. All the rocks and naked boulders were covered with an immense number of large iguanas, with Gecko lizards and spotted salamanders. Motionless, with raised heads and widely gaping mouths, these cold-blooded creatures seemed to inhale with delight the heated air. The larger animals are then concealed in the shades of the forest, the birds under the foliage of the trees or in the crevices of the rocks; but on listening attentively to the faintest tones which interrupt the apparent silence of nature, one hears a hollow murmuring, and a humming and buzzing of insects near the ground and in the lower strata of the atmosphere.

With the excessively high temperatures above-mentioned, the enormous cold which sometimes takes place in winter forms a remarkable contrast. Near London, the thermometer has been known to fall to −5°, and in town to +11° F. Paris has experienced a cold of −10·5°, Hamburg and Berlin of −22°; and still farther to the north or east (where the continental influence shows itself in the increasing severity of winter) we find at Breslau a maximum of cold of −31°, at St. Petersburg of −37°, and at Moscow of −44°, not to mention Enontekis in Lapland, where −58° has been observed.

On turning to the arctic regions of Asia and America, we find still more excessive instances of cold. At Nishnei Kolymsk, which was Wrangell's[1] delightful residence during three consecutive winters, the thermometer once fell to −65°; and at Jakuzk which, if not the most agreeable, is apparently the coldest town on earth, to −72·5°. Temperatures as low as −65° are said to be by no means uncommon in that delectable place where, during two months in every year, mercury is a solid body. Then breathing becomes difficult, and even the reindeer seeks a shelter in the woods, and remains motionless as if deprived of life. In America we find noted as the lowest temperatures, −55° on Melville Island, −57° at Fort Enterprise, and −70° at Fort Reliance. During the first terrible winter which Kane passed in Rensselaer Harbour (78·5° N. lat.) the thermometers ranged from 60° to 75° below zero; and one instrument, on which great reliance could be placed, stood upon the taffrail of the brig at −65°. The reduced mean of the best spirit standards gave −67°, or 99° below the freezing point of water.

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[1] 'Travels in Siberia.'

At these temperatures chloricether became solid, and carefully prepared chloroform exhibited a granular pellicle on its surface. The exhalations from the surface of the body invested the exposed or partially clad parts with a wreath of vapour. The air had a perceptible pungency upon inspiration, but Kane could not perceive the painful sensation which has been spoken of by some Siberian travellers. When breathed for any length of time, it imparted a sensation of dryness to the air-passage. He noticed that, as it were involuntarily, he and his companions all breathed guardedly with compressed lips.

It may be asked how man is able to bear these extremes of heat and cold. A thin clothing, frequently even among the natives no clothing at all; repose in the shade during the hottest hours of the day, the construction of the houses which keeps out as much as possible the sun and sultry winds; the increased perspiration which lowers the temperature of the skin by evaporation; the use of cooling beverages and a sparing, principally vegetable, diet, renders even a tropical summer very endurable; while a low hut half-buried in the ground, and covered with a high heap of snow, a double clothing of skins, and the consumption of enormous quantities of flesh and fat, enable the Esquimaux to brave the rigours of the arctic wilderness. Another circumstance which generally renders extreme cold more endurable is the absence of wind.

Thus we see man able to inhabit climates ranging from a cold of 90° or more below the freezing point of water to a warmth of more than 100° above it. For a short time he is even able to bear a much greater heat than any which the sun produces above the surface of the earth. Dr. Fordyce stayed for a considerable time, and without great inconvenience, in a room heated by stoves to 260° of Fahrenheit's scale. The lock of the door, his watch and keys lying on the table, could not be touched without burning his hand. An egg became hard; and though his pulse beat 139 times per minute, yet a thermometer held in his mouth was only 2° or 3° hotter than ordinary. He perspired most profusely,[1] and it was the cold generated by the evaporation of this moisture which enabled him for a short time to bear a temperature that would have cooked a beefsteak. Evaporation is, in fact, the waste-pipe or safety-valve which, under the most varying conditions of climate, maintains the temperature of the blood at the constant level of 36·6° C. Increasing or diminishing as the temperature of the air rises or falls, it explains how the blood of the Hindoo is not warmer than that of the Esquimaux, and how an Englishman, in sailing through every zone, finds his blood temperature hardly heightened by his approach to the equator, and hardly diminished on his entering the regions of perpetual winter.

The highest and the lowest atmospherical temperatures hitherto recorded are no doubt often surpassed, for the earth is large, and thermometrical observations are comparatively few. Our knowledge of the extreme climates is, indeed, very limited, for being either totally uninhabitable or the abodes of vagrant barbarians, they afford but few opportunities for meteorological observations. Thus in the sultry deserts of Africa or Asia there are probably many close dells where the heat in the shade is at times superior to that which has been measured at Murzuk.

On the desolate plateaux of the polar zone there can likewise be no doubt that the extreme cold of winter falls below the level observed by navigators on the shores of the Arctic Sea. On October 22, 1860, Dr. Hayes set out from Port Foulke (78° N. lat.), in Smith's Sound, on an exploring visit to the great Humboldt Glacier. On the 24th, having ascended to a height of 5,000 feet on the back of the glacier, the temperature fell to 30° below zero, and a fierce gale of wind meeting the travellers in the face, drove them into their tent for shelter, and after a rest of a few hours compelled them to return. The temperature fell to 34° below zero during the night; while the lowest record of the thermometer at Port Foulke, during Dr. Hayes' absence, was 22° higher. The men complained bitterly (as well they might), and could not sleep. The storm steadily increased in force, and the temperature falling lower and lower, they were all at length forced to quit the tent, in order to prevent themselves from freezing by active exercise. To face the wind was not possible, and shelter was nowhere to be found upon the unbroken plain.

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[1] 'Philosophical Transactions,' vols. lxiv. and lxv.

There was but one direction in which they could move, and that was with their backs to the gale. It was not without much difficulty that the tent was taken down and bundled upon the sledge. The wind blew so fiercely that they could scarcely roll it up with their stiffened hands. The men were suffering with pain, and could only for a few moments hold on to the hardened canvas. Their fingers freezing continually, required active pounding to keep them upon the verge of life. 'Our situation at this camp,' says the bold explorer,[1] 'was as sublime as it was dangerous. We had attained an altitude of 5,000 feet above the level of the sea, and we were 70 miles from the coast, in the midst of a vast frozen Sahara, immeasurable to the human eye. There was neither hill, mountain, nor gorge anywhere in view. We had completely sunk the strip of land which lies between the *mer de glace* and the sea, and no object met the eye but our feeble tent which bent to the storm. Fitful clouds swept over the face of the full-orbed moon, which, descending towards the horizon, glimmered through the drifting snow that whirled out of the illimitable distance, and scudded over the icy plain; to the eye, in undulating lines of downy softness; to the flesh, in showers of piercing darts. Our only safety was in flight; and, like a ship driven before the tempest which she cannot withstand, we turned our backs to the gale, and, hastening down the slope, we ran to save our lives. We travelled upwards of 40 miles, and had descended about 3,000 feet before we ventured to halt. The wind was much less severe at this point than at the higher level, and the temperature had risen 12°. We reached Port Foulke the next evening, after a toilsome march, without having suffered any serious accident.' If, then, Dr. Hayes found so great a difference of temperature on the coast and on the glacier, and experienced as early as the month of October 66° below the freezing point of water, at the moderate elevation of 5,000 feet, the hibernal mountain blasts of Port Foulke must be terrible indeed.

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[1] 'The Open Polar Sea,' p. 134.

The following instances of remarkably severe winters and warm summers that have occurred in Europe show us that our temperate countries are exposed from time to time both to the ardours of the torrid zone and the intense frost of the Arctic world:—In the years 860 and 1234, goods were transported from Venice to the opposite Dalmatian coast over the frozen Adriatic. During the winter 1621–22 the fleet was ice-bound near Venice; and in 1709 the Adriatic is said to have been completely covered with ice. In 1305 and 1364, all the rivers were frozen in France, and on the Rhône the ice was in some parts 15 feet thick. In 1709, the sea at Cette and Marseilles was covered to a great distance with ice; most of the fruit trees were destroyed by the cold, and daily the bodies of persons who had been frozen to death were found on the roads.

The winter of 1788–89 was one of the longest and most rigorous that ever reigned in Europe. In Paris the cold commenced on November 25, and lasted, with one single short interruption (December 25), for fifty consecutive days. The usually rapid Rhône was quite frozen over at Lyons, and the Garonne at Toulouse. Along the coasts of the Atlantic the sea froze to a distance of several leagues, and vessels could not approach within many miles of the port of Ostend, which in ordinary winters is constantly open. The Thames was frozen as far as Gravesend, and during the Christmas holidays the river was covered with booths. The birds which generally inhabit the northern regions showed themselves in several provinces of France; and the fish perished in almost all the ponds, on account of the thickness of the ice.

The severe winter of 1812–13 can never be forgotten as long as the name of Napoleon I. lives in the memory of man. The cold began at an early date all over Europe. The first snow fell at Moscow on October 13, and the retreat of the French army from that doomed city commenced on the 18th. On November 9, the thermometer stood at + 5° F., and on the 17th it fell to − 15°, according to Baron Larrey, who carried a thermometer suspended from his button hole. It would lead me too far were I to give even a brief account of the accumulated horrors of that dreadful march; suffice it to say, that 450,000 men perished from cold and hunger, while the modern Xerxes, enjoying the warmth of a good fire at Warsaw, told his ambassador, the Abbé de Pradt, that he had never felt better in his life.

The winter of 1813–14 was so severe in the south of England that on February 3, 1814, a sheep was roasted on the frozen Thames, and bills were everywhere stuck up with the inscription, 'A safe footway over the river to Bankside.' On the 7th a paper was sold, 'printed to commemorate a remarkable frost which commenced December 27, 1813; a fair, February 4, 1814, held, and the whole space between London and Blackfriars Bridges covered with spectators.'

The winter of 1840–41, which also ranks among the severest of this century, reigned from December till March over a great part of Western Europe. On December 15, the body of Napoleon I., on its way from St. Helena to the Church of the Invalides, was carried in solemn procession through the Champs Elysées. Innumerable spectators, the National Guards of Paris and of the environs, and an army of soldiers, were assembled all along the line of march from the early morning till 2 o'clock in the afternoon; and that this long waiting to see the funeral procession pass was by no means agreeable may be inferred from the fact that the thermometer on that day marked as low as + 6·8° F. Some of the National Guards and workmen, endeavouring to warm themselves by drinking brandy, were seized by the cold, and dropped down dead of congestion to the brain. Others—the martyrs of sight-seeing—having climbed up into the trees, to enjoy a better view, their extremities, stiffened by the cold, failed to support them, and they were killed by the fall. Thus, even the remains of the man who, while living, had cost the lives of millions, could not be brought to rest without having levied the last tribute of a hecatomb of victims.

What a contrast between these instances of killing frost and the ardours of a hot summer, like that of 1793, when on July 16 the thermometer marked in London 89° in the shade, and on the 8th of the same month 101·1° in Paris. The intense heat began in the latter city on July 1, and lasted no less than 51 days, with a thermometrical range of from 78° to 95° and more. On August 7 the heat was particularly oppressive, the north-east wind which blew at the time being so sultry that it seemed to issue from a furnace or a big kiln. It paralysed respiration, and though the thermometer only stood at 87°, the heat was more intolerable than on July 8, when it marked 101°. The drought was excessive; since 1719, the waters of the Seine had never been so low. Only 231 millimetres of rain fell at Paris during the whole year. In the country the leaves of the vines and fruit trees were scorched; vegetables were excessively rare, and sold at exorbitant prices. The soil, hardened and creviced by the heat, could neither be ploughed nor dug. In the gardens of the Luxembourg the ground was thoroughly dried up to a depth of three feet and a-half. On September 1, the trees of the Palais Royal were almost entirely stripped of their leaves; 150 of them were completely bare, and many of them died. In the neighbourhood of Toulouse the maize crop entirely failed, and it was altogether a year of great scarcity in France.

The hottest summer during the first half of this century was that of 1842, particularly in the north of France, Belgium, and England. In Paris the temperature of June was 55° F., and that of August 7·2° above the ordinary mean. Many accidents were caused by the excessive heat. In Spain, the wheels of several post-carriages took fire. In many places the labourers working in the fields fell down asphyxiated, and frequent cases of insanity were attributed to the sultry heat.

During the hot summer of 1852 the thermometer rose in London (July 12) to 95° in the shade. In Central France, it stood for more than ten consecutive days above 86°. Many domestic animals perished while labouring in the fields.

The difference between these instances of extreme summers and winters, and the following examples of winters remarkable for their mildness and summers unusually cold, is so immense that it seems to transport us to countries belonging to different zones.

Steinhofer, in the 'Würtemberg Chronicle' of the year 1289, tells us that snow did not fall once during the whole of the mild winter. At Christmas the trees began to bud, the strawberries ripened in February, and in April some vines were found to blossom; but in May the scene completely changed. As if the order of the seasons had been inverted, snow fell, and it became so cold that the vines and fruit blossoms were frozen. But as it was yet so early in the season, the vines put forth new blossoms and produced wine.

The year 1186 was still more remarkable, for Martin Crusius informs us in his 'Swabian Chronicle' that the apple trees blossomed in January, and that in February their fruits were already as big as hazelnuts. The harvest took place in May, and the vintage in August.

The late and short summer of 1835 had a very different effect on vegetation, for towards the end of June and the beginning of July there was such an extraordinary fall of the temperature in France that the mountains at Bourbon and in the Auvergne were covered with snow, and the plains every morning with hoar frost. On July 21, 1832, the temperature in South Germany fell so considerably after an intense heat that in some of the more elevated districts of Würtemberg the potatoes and cereals were frozen.

Sometimes there is a succession of two or more cold winters and warm summers, and frequently, while a mild winter or a very warm summer reigns in some countries, the opposite takes place in others.

The winter of 1739–40, for instance, was uncommonly severe in England. 'The river Thames was covered with such a crust of ice that a multitude of people dwelled upon it in tents, and a great number of booths was erected for the entertainment of the populace. The navigation was entirely stopped, the watermen and fishermen were disabled from earning a livelihood, and the fruits of the earth were destroyed by the cold, which was so extreme that many persons were chilled to death.'[1] On February 26, 160 sledges crossed the Zuiderzee from Stavoren to Enkhuizen, and near Ostend the German Ocean was frozen as far as ten miles from the coast. From eight to ten feet of snow fell in Portugal and Spain, and in Poitou the mortality was dreadful in consequence of the cold. All this time, the winter was uncommonly mild in Iceland and Greenland.

The winter of 1821–22 was remarkably warm all over Germany, and even in Russia and Siberia, so that Tobolsk and St. Petersburg had scarce two months of lasting cold. On the other hand, the temperature in South America was unusually low, and on February 20 snow fell at Buenos Ayres—an almost unexampled occurrence.

During the winter of 1829–30, which was so severe in south-western Europe that the Lake of Constance, for the first time within the memory of man, was completely frozen over, and in Spain the people could hardly protect themselves against the cold, the United States enjoyed a very mild temperature.

The contrary took place in the winter of 1834–35, which was remarkably mild, particularly in North Germany, so that in Berlin, from January 1 to March 18, the thermometer fell only during ten days below the freezing point of water. All this time a terrible cold reigned in America. In the beginning of January, the ports of Boston, Philadelphia, and Baltimore were completely frozen. In several towns situated in the latitudes of Genoa and Milan the mercury congealed in the thermometers. In February the cold was so intense that the temperature fell to $-9{\cdot}8°$ at New Orleans, to $-12{\cdot}9°$ at Savannah, and to $-13{\cdot}3°$ at Charlestown, so that a cold but very rarely experienced in England reigned in the latitude of Cairo.

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[1] Smollet's 'History of England.'

The effects of this unusually low temperature on the vegetation were dreadful. Near Jacksonville, on the St. John's River, the orange trees were split by the cold down to the roots. The evergreen oaks lost their foliage, and only began to put forth new leaves on March 20. The irruption of the cold American air into the European atmosphere took place with remarkable energy. At the beginning of Easter week, summer might have been supposed to reign in North Germany; but now a rapid change took place, for the snow fell thickly on Good Friday. The Rhine had a completely wintry aspect, although the peach and cherry trees were in full blossom. In England the transition was still greater. It snowed as in December, and it froze even during the daytime in exposed places. The stage coaches which drove on Good Friday from the north of England to London were completely covered with snow. This transposition of the seasons put people very much in mind of the old weather rules:—

If the grass grows in Janiveer,
It grows the worse for all the year,

and

If Janiveer Calends be summerly gay,
'Twill be winterly weather till the Calends of May.

On March 1, 1845, all the railroads in Germany were covered with snow. On February 14 the Rhine was completely frozen over at Mannheim. About this time a severe cold reigned in Algiers and Morocco, so that the coasts, as well as the opposite shores of Spain, were covered with snow. Snow fell on March 12 near Montpellier, and as late as the middle of May in the Vosges Mountains and the Black Forest. Near Prague the river Moldau was covered during 114 days with ice. Vegetation was considerably retarded by this long-continued cold. Near Brussels the snowdrops blossomed thirty-one days later than usual. While Europe thus suffered from excessive cold, North America enjoyed a mild winter.

The contrary took place in 1872-73, for, while it hardly froze in Central Europe, the cold was excessive in America. On Christmas Day, the snow fell in such quantities in New York as to block the streets. Dreadful snowstorms raged over Indiana, Missouri, and Tennessee, while, at the same time the weather was uncommonly mild at San Francisco. Railway traffic was everywhere interrupted, and many guards had their extremities frozen. In Wisconsin the thermometer marked 30° below zero.

From a complete series of authentic observations of the monthly mean temperatures of fifty-nine meteorological stations, Professor Dove concludes that when a large portion of the earth's surface is taken into account, the apparent anomalies of particular seasons counterbalance one another, so as to give no countenance to the opinion that the heat which the sun imparts to the earth varies in different years. The necessary consequence is that when one part of the world enjoys or suffers an uncommonly mild summer, or a winter of unusual severity, the opposite phenomenon must show itself in other countries.

Sir John Herschel and M. Pouillet have calculated that the total amount of solar heat received by the earth in a year, if distributed uniformly over its surface, would be sufficient to liquefy a layer of ice 100 feet thick, and covering the whole earth. It would also heat an ocean of fresh water sixty-six miles deep from the temperature of melting ice to the temperature of ebullition. And yet but an infinitesimally small part of the heat emitted by the sun falls to the share of our planet, for the sun radiates its heat in every direction, and the surface which the earth exposes to its rays is so small in comparison to the vast ethereal spaces through which they are speeding on all sides into the unknown infinite, that it interrupts but $\frac{1}{2,300,000,000}$ of the total radiation.

And all this prodigal expenditure of heat has been going on for countless ages, nor has it been found to suffer the slightest diminution since the first dawn of history. It still ripens the vine and the date in Palestine as it did in the patriarchal times, and the cedars of Lebanon still flourish as when they furnished timber for the fleets of Solomon. Well may we ask whether a period is ever to come when the sun will be wandering cold and inert through space, and by what means its heat is constantly repairing its wasted power?

The sun is generally considered as the only external source from which our earth derives it warmth; but the moon also not only sends us her mild and friendly light, but also some heat which, in spite of its almost inappreciable faintness, has been detected by the consummate skill of a Melloni. And as luminous rays are also calorific rays, we can hardly doubt that if instruments sufficiently sensitive were in our power we should be able to find that heat is imparted to us even by the radiation of the stars.

Our earth itself contributes to the warmth of the atmosphere. Every active volcano, every warm spring, is a source of heat independent of the sun. The friction of the wind, the hail striking the ground, the grinding of the glacier, and the wave that dashes against the shore, all produce heat, and its evolution takes place whenever the ice-fields of the polar ocean clash against each other.

CHAPTER VII.

THE WINDS.

The Migrations of the Air—Salutary Influence of the Winds—Aeolus—The Winds personified as Gods by the Ancients—The 'Tower of the Winds' in Athens—Boreas—Zephyrus—Hindoo Prayer to the Winds—'Ye Viewless Minstrels of the Sky'—Origin of the Winds—Solar Heat—The Ascending Equatorial Air-Stream—The Polar Air-Streams—Influence of the Earth's Rotation on the Direction of the Winds—The Trade Winds—The Belt of Calms—The Monsoons—Their Influence on the Early Development of Navigation—Their Causes—The recurrent Equatorial Air-Stream—Inconsistency of the Winds in the Temperate Zones—Dove's Law of Rotation of Winds—Winds in the Arctic Regions—Land and Sea Breezes—Hill and Valley Breezes—Mountain Breezes on the Cordilleras—Velocity of Winds—Storm Winds in Norway and Iceland—The 'Great Storms' in England (1703)—The Bora—The Mistral—The Simoom and Khamsin—The Tebbad—The Harmattan—Hot Winds of the Kalahar Desert described by Dr. Livingstone—The Sirocco—The Solano—The Fön.

THE atmosphere is even more turbulent and unruly than the rolling sea. Never, since it first encompassed the earth, has it known a moment's rest; never, as long as our globe exists, will it enjoy repose. At all times, in all places, it is constantly striving after a uniform temperature, a uniform weight and density; but a thousand conflicting influences no less constantly and energetically oppose this equalising tendency. In vain, to restore the disturbed equilibrium, the winds rush from all points of the compass; new disturbances are constantly arising, and thus in the atmosphere, as in the life of man, we find a perpetual striving after rest, equally unattainable for both. The air is indeed the greatest wanderer on earth; in the course of centuries each of its particles undergoes numberless displacements and perpetual changes. Now absorbed by the waters, it dives into the depth of ocean, and then again it soars aloft into the highest atmospherical regions, from which it looks down upon the snowy peaks of the Himalaya, or sees far below the eagle wheeling in majestic circles. Now it softly murmurs in the palm tops of the Orinoco, and then again it raves with stormy violence over the gloomy cliffs of Fuegia. From the wretched hovels of poverty it wings its unseen way into the gorgeous palaces of wealth, and rushes in rapid flight from the crowded city to the greenwood or the solitary glen. Now polluted with malaria, it rests over the pestilential swamp, and now it is wafted along in the pure mountain breeze. Who would not wish for similar wings? who would not feel happy to wander thus free and unshackled over the surface of the earth.

But though we are unable to sail through the aerial regions with the light pinions of the wind, we still can follow the beneficial wanderings of the never-resting atmosphere on the wings of thought. On its eternal fluctuations depends the existence of the whole organic creation; for if the air had been a stagnant, or even a less movable, element, neither plant nor animal could ever have thrived or appeared upon the scene of life. Dispersing all noxious exhalations as they arise, the perpetual air-currents convey to all that breathe the vital element in its necessary purity; they scatter the seeds and fertilising germs of unnumbered plants over the earth, and cover the naked rock with a verdant robe; they carry the emanations of the ocean, without which all land would be a desert, far into the interior of the continents; and before steam was invented they alone opened the highway of the seas to the human race. Compared with benefits like these, the devastations of the tornado and cyclone are evils insignificantly small.

The important part which the winds perform in the economy of nature, and their immense influence upon the welfare of mankind, could not fail to assign them a conspicuous place in the religious traditions of the heathen world. According to ancient fable, Aeolus, the god or ruler of the winds, had his seat in Aeolia, one of the Lipari Islands, in whose cavernous recesses his unruly subjects were confined. Virgil beautifully describes the restless island of the storms—

Where in a spacious cave of living stone
The tyrant Aeolus, from his airy throne,
With powers imperial curbs the struggling winds,
And sounding tempests in dark prison binds.—DRYDEN'S '*Æneid.*'

In Homer we find the winds personified as gods. When Achilles set fire to the funeral pile of Patroclus—

He victims promised and libations cast
To gentle Zephyr and the Boreal blast,
And called th' aerial powers along the skies
To breathe and whisper to the fires to rise.
The winged Iris heard the hero's call,
And instant hastened to their airy hall,
Where in old Zephyr's open courts on high,
Sat all the blustering brethren of the sky.

She told them of the rich offerings which Achilles had vowed to bestow upon them as a reward for their kindly offices, and—

Swift as the word she vanished from their view,
Swift as the word the winds tumultuous flew,
Forth burst the stormy band with thundering roar,
And heaps on heaps the clouds are tost before;
To the wide main, then stooping from the skies,
The heaving deeps in watery mountains rise.
Troy feels the blast along her shaking walls,
Till on the pile the gather'd tempest falls;
The structure crackles in the roaring fires,
And all the night the plenteous flame aspires.

In Sicyon an altar was raised to the winds, on which once a year offerings were made to them by night; and in Delphi a temple was specially dedicated to their service. In the 'Tower of the Winds' at Athens, Boreas, the stormy northern blast, was represented as a gloomy-looking bearded figure. His warm clothing reminded the spectator of the piercing cold which accompanies his approach, his sea-shell horn of the hollow sound of his voice, and his dark-coloured wings of the black clouds he frequently drives before him. The Athenians invoked his aid against the fleet of Xerxes, and his friendly blast destroyed part of the Persian ships at Cape Sepias. To testify their gratitude, an altar was raised to Boreas on the banks of the Ilissos.

On the opposite wall of the tower appeared the youthful figure of Zephyros, the mild west wind, loosely clad with a light, flowing mantle, in the folds of which he carried bunches of flowers, to symbolise the revival of all nature by his humid and genial breath. The soft south wind, Notus; the south-west wind, Libs; and the east wind, Apeliotes, which brought fertilising showers to Athens from across the sea, were likewise represented as cheerful youths; while Eurus, the sultry south-east, and Cæcias, the damp and cold north-east, with his attendant train of storm and hail, of clouds and snow, had morose and forbidding features. Thus the lively imagination of the Greeks gave to each wind a characteristic form, and felt in each breath of the air the agency of a spiritual power.

In India, where drought and rain, scarcity and plenty, vary with the changing monsoon, the winds have, since time immemorial, been revered as influential deities, ruling the whole destiny of man. In the ancient hymns of the Rig Veda, one of the oldest literary documents in existence, the pious Hindu appears essentially impressed by the might of the elements, whose assistance and favour he frequently invokes. He prays to the Maruts or winds to bring him rain, the harbinger of plenty; he complains to them of his troubles, and reminds them of the wonderful deeds they performed of yore, to coax them, as it were, into a friendly help. 'We proclaim eagerly, ye winds, your ancient greatness, for the sake of inducing your prompt appearance on the indication of the approach of the "showerer of benefits."' Such is the strain in which the Hindu of that period addressed the winds.

Civilised man has long since ceased to deify or personify the various movements of the air. We no longer erect temples to their honour, or lay gift offerings on their altars; but to the moralist they ever will afford a fruitful theme for reflection; and the poet,

who gives to airy nothing
A local habitation and a name,

loves to apostrophise them, as if Aeolus still dwelt in his cave, or Boreas still blew his hoarse-resounding horn.

Ye viewless minstrels of the sky!
I marvel not in times gone by,
  That ye were deified:
For, even in this later day,
To me oft has your power or play
  Unearthly thoughts supplied

Awful your power! when by your might
You heave the wild waves, crested white,
  Like mountains in your wrath: .
Ploughing between them valleys deep,
Which to the seaman roused from sleep,
  Yawn like Death's opening path.

Graceful your play! when round the bower
Where beauty culls Spring's loveliest flower
  To wreathe her dark locks there;
Your gentlest whispers lightly breathe
The leaves between, flit round the wreath,
  And stir her silken hair.—BARTON.

Indeed, few other atmospherical phenomena have so direct an influence on the inconstant fortunes of man, or more forcibly impress upon his mind the sense of his dependence on the irresistible powers of nature. Now gently whispering, and now terrific in their rage, beneficial and destructive, friendly and hostile, the ever-changing agents of good and evil, they appeal both to the fancy of the bard and the meditation of the philosopher.

Thus, when Horace, in one of his finest odes, advises his friend Licinius to hold fast the golden mean, he reminds him that the tallest pines feel most the power of the wintry blasts, and admonishes him to draw in half his sails when swollen by a too propitious breeze—

Sapienter idem
Contrahes vento nimium secundo
Turgida vela.

Like the oceanic currents, all the winds that blow are originally derived from the heat of the sun. Warmed air expands, becomes lighter, and consequently rises to a higher level; cooled air contracts, becomes heavier, and sinks. This simple principle or law which compels the air to ascend in our lighted lamps or in our heated chimneys, which, when on a cold day we open the door of a warmed room, causes a current of light air to rush out at the top while a cold current flows in at the bottom, is constantly operating throughout the whole mass of the atmosphere and never leaving it at rest.

The rays of the sun, coming into contact with the earth, heat its surface, and when they fall upon the ocean they provoke evaporation. The air in contact with the surface shares its heat, expands, and is rendered sufficiently buoyant to rise upwards, while the vapour from the ocean also ascends on account of its lightness, carrying air along with it. But the surface of the earth is composed of a great number of substances, which are very unequally heated by the solar rays, and this inequality shows itself even over spaces of limited extent. Supposing the sun's warmth to be equal, certain bodies absorb it more readily than others, so that different degrees of temperature are imparted to the contiguous air. Thus in the daytime, a lower temperature generally prevails in the shade of houses, trees, and clouds, over sheets of water, meadows, and forests, than over masses of stone, roofs, and sandy plains. If, therefore, we suppose a particular spot or tract of land to be heated by the sun while an adjoining part remains comparatively cool, the immediate consequence is that an upward current rises from that spot, and ascends into the higher regions of the air. But as it rises, its place below must be occupied by an equal bulk of air, which is necessarily derived from the sides. A current is thus immediately established, an ascending stream in the one case, and a horizontal flow of greater or less force in the second. Slight movements of the air arising from this cause may be observed on any sunny day on a forest border, under shady trees, on the banks of rivers, or on the sea strand; and the mighty winds which are constantly migrating from one zone to another merely exhibit the same phenomenon on the grandest scale.

Wherever in the torrid zone the sun culminates in the zenith, the air, rarefied by the intense heat of its vertical beams, ascends in perpendicular columns high above the surface of the earth, and thence flows off towards the poles, in the same manner as in a vase filled with cold water and placed over the flame of a lamp, the warmed liquid rises from the bottom and spreads over the surface. To fill up the void, cold air currents are constantly flowing in an opposite direction from the poles to the equator, as in the example above cited, colder and consequently heavier water comes streaming down the sides of the vase, to replace the liquid which is rising in the centre under the influence of heat.

Thus the unequal distribution of solar warmth in different latitudes gives rise to a constant circulation of air from the lines to the poles (equatorial current), and from the icy regions to the tropics (polar currents), a most beneficial interchange, which conveys part of the warmth generated in the torrid zone to the gelid extremities of the earth, and at the same time alleviates the intolerable heat of the equatorial regions.

If the earth were motionless, these opposite air currents would necessarily run directly north and south; but our earth, as we all know, rotates from west to east round its axis once in twenty-four hours. In virtue of this rotation, the air at the equator is carried round with a velocity of 1,000 miles an hour; but on withdrawing from the equator, the velocity due to the earth's rotation diminishes, and it becomes nothing at the poles, just as the rim of a wheel moves faster in the same time than any part of the axle.

The consequence is, that the equatorial current, as it advances towards the north, or passes from places of quick motion to places of slow motion, is deflected more and more towards the east, and tends to become a westerly wind, while the polar current, which started as a north wind, follows the direction of the earth's rotation, and, as it approaches the equator, becomes more and more easterly.

The motion westward of the polar air-streams is increased by another circumstance. Since the rarefaction of the air in the torrid zone is owing to the heat derived from the contiguous earth, and since the heat is due to the perpendicular rays of the sun, those parts must be hottest where the sun is actually vertical, and consequently the air above them must be most rarefied; the contiguous parts of the atmosphere will therefore be drawn most forcibly to that particular spot. Now, since the diurnal motion of the earth is from west to east, this hottest spot will be continually shifting westwards, and this will occasion a current of the atmosphere in that direction.

The air-streams which, flowing from the poles to the equator, are thus forced to assume the character of easterly winds as they advance, blow regularly the whole year round over a considerable part of the Atlantic and Pacific Oceans. On account of the certainty with which they waft our ships across the tropical seas from east to west, they have been called the trade winds. The history of maritime discovery tells us that by their assistance Columbus was enabled to discover America, and the wretched barks of Magellan to traverse the wide deserts of the Pacific from end to end.

In the northern Atlantic, their influence, varying with the seasons, extends to 22° N. lat. in winter, and 39° N. lat. in summer; while in the southern hemisphere they reach no further than 18° S. lat. in winter, and 28° or 30° S. lat. in summer. In the Pacific their limits vary between 21° and 31° N. lat. and between 23° and 33° S. lat., so that on the whole they have here a more southern position, owing, no doubt, to the vast extent of open sea, which favours their unimpeded progress; while in the Atlantic the influence of the neighbouring continents forces them to the north, and even causes the trade winds of the southern hemisphere to cross the equatorial line. The character of the trade winds is that of a constant soft breeze, strongest in the morning, remitting at noon, and again increasing in the evening. In the neighbourhood of the coasts, except over very small islands, they become weaker, and generally cease to be felt at a distance of about fifteen or twenty miles from the sea.

For obvious reasons the trade winds have been much more accurately investigated upon the ocean than on land, particularly in the northern Atlantic, which, from its being the highway of numberless vessels to which the study of the winds is a matter of the greatest importance, is better known in its meteorological phenomena than any other part of the ocean. Yet over the continents also their course has been ascertained by travellers. North-easterly winds almost constantly sweep over the Sahara, and Dr. Livingstone informs us that in South Africa easterly winds blow over the whole continent even as far as Angola, where they unite with the sea winds. In Brazil the presence of the trade winds has been pointed out with still greater accuracy. Thus easterly breezes almost perpetually sweep over the boundless plains of the Amazons, up to the slopes of the Andes, and even in

Paraguay (25° S. lat.), a mild east wind constantly rises in summer after the setting of the sun.

The trade winds of the northern and southern hemispheres do not, however, unite and flow in one undivided current over the whole breadth of the great tropical ocean, but are separated from each other by an intermediate zone or belt of calms, occasioned by their mutually paralysing each other's influence on meeting from the north and the south; and by the power of the sun, which, when in the zenith, changes the easterly currents into an ascending stream. From this dependence on the position of the sun, it may easily be inferred that tho zone of calms fluctuates along with the trade winds, to the north or south according to the seasons; and that it is far from invariably occupying the same degrees of latitude, or the same width, at all times of the year. In the Atlantic it constantly remains to the north of the equator, where its breadth averages five or six degrees; in the Pacific it more generally extends, during the antarctic summer, on both sides of the equator. In the Indian Ocean, the trade wind blows constantly from 10° S. lat. to near 30°; but to the northward of this, the winds change every six months, and blow directly opposite to their former course. These regular winds are called *monsoons*, from the Malay word *moossin*, which signifies a season. When they shift their direction, variable winds and violent storms succeed, which last for a month, and frequently longer, and during that time it is dangerous for vessels to continue at sea.

The monsoons in the Indian Ocean may be reduced to two—one on the north and the other on the south side of the equator, which extend from Africa to the longitude of New Holland and the east coast of China, and which suffer partial changes in particular places from the situation and inflection of the neighbouring countries.

Between 3° and 10° of S. lat. the south-east trade wind continues from April to October, but during the rest of the year the wind blows from the north-west. Between Sumatra and New Holland this monsoon blows from the south during our summer months, approaching gradually to the south-east as we advance towards the coast of New Holland; it changes about the end of September, and continues in the opposite direction till April. Between Africa and Madagascar its direction is influenced by the coast, for it blows from the north-east from October to April, and during the rest of the year from the south-west.

Over all the Indian Ocean to the northward of the third degree of S. lat., the north-east trade wind blows from October to April, and a south-west wind from April to October.

From Borneo, along the coast of Malacca and as far as China, this monsoon in summer blows nearly from the south, and in winter from the north by east. Near the coast of Africa, between Mozambique and Cape Guardafui, the winds are irregular during the whole year, owing to the different monsoons which surround that particular place. Monsoons are likewise regular in the Red Sea; between April and October they blow from the north-west, and during the other months from the south-east, keeping constantly parallel to the coast of Arabia.

As the trade winds of the Atlantic greatly facilitated the conquest and colonisation of tropical America by the Spaniards, thus, also, the regularly alternating monsoons materially contributed to the early development of navigation in the Indian seas, and wafted the barks of the Phœnicians, and after them of the Greeks and Romans, as far as Ceylon, Malacca, and the Gulf of Siam.

The trade wind would blow regularly round the whole globe if the torrid zone were all covered with water; and consequently the changes imparted to its direction in the Indian Ocean are owing to the influence of the land.

When the sun approaches the tropic of Cancer, India, China, and the adjacent countries, become much hotter than the water which washes their southern coast. The air above them becomes rarefied and ascends, while colder air comes rushing in from the Indian Ocean to supply its place. As this current of air moves from the equator northward, it must, for a reason already explained, assume the appearance of a south-west wind; and this tendency eastward is increased by the situation of the countries to which it flows. This is the cause of the south-west monsoon. Between Borneo and the coast of China its direction is almost due north, because the country to which the current is directed lies rather to the west of north, a circumstance which counteracts its greater velocity.

In winter, when the sun is on the south side of the equator, these countries become cool, and the north-east trade wind resumes its course, which had it not been for their interference, would have continued the whole year.

As the sun approaches the tropic of Capricorn, it becomes almost perpendicular to New Holland; that continent is heated in its turn, the air over it is rarefied, and colder air rushes in from the north and west to supply its place. This is the cause of the north-west monsoon, which flows from October till April from 3° to 10° S. lat. Near Sumatra its direction is regulated by the coast; this is the case also between Africa and Madagascar. The same cause which occasions the Indian monsoons gives rise to similar deflections from the ordinary course of the trade winds in other parts of the torrid zone. Thus, on the coast of Guinea, in the Mexican Gulf, and in that part of the Pacific which borders on Central America, we find the influence of the heated plains of Africa, Utah, Tejas, and New Mexico, giving rise to a total change in the direction of the wind during the summer months.

Having thus briefly traced the progress and fluctuations of the air-currents which come pouring in from the poles, to replace the ascending equatorial air-stream, we will now follow the latter in its course to the higher latitudes. As it rises into the upper regions of the air, it loses part of its heat through expansion, and its current is now deflected towards the north and south, to replace the polar streams. Gradually descending to a lower level on its progress to the higher latitude, it first reaches the earth in the northern hemisphere at about 30° lat. in summer, and a few degrees more to the south in winter. In consequence of its movement from the swiftly rotating equator to regions of decreasing velocity, this recurrent equatorial air-stream takes the apparent character of a wind from west to east, and consequently appears on our latitude as a westerly wind.

Thus the mild zephyrs which sometimes greet us in the depth of winter have generally travelled all the way from the West Indies to our shores, and may have risen from the bosom of the Caribbean Sea a few weeks before they mingled with the smoke of London.

The recurrent equatorial air-stream was long suspected to exist before its existence was positively ascertained by a curious accident. In 1822 an immense volcanic eruption took place in the island of St. Vincent, and vomited to an enormous altitude showers of stones and ashes. Strange to say, although the trade wind blows so strongly in the opposite direction, that a circuit of 100 miles is necessary to enable vessels to reach Barbadoes from St. Vincent, a quantity of volcanic ashes fell on the island of Barbadoes, which undoubtedly had their origin in the eruption at St. Vincent. The only explanation of this singular event was founded upon the existence of this upper or back current. The power of the volcano had projected these ashes entirely through the lower current into the uppêr, and, after being carried by it, they were dropped into Barbadoes. In the same manner, the shower of ashes which in 1835 fell upon the town of Kingston in Jamaica, in consequence of an eruption of the volcano Cossiguina, could only have been carried there by the upper or equatorial current. Another curious confirmation of its existence is recorded by Humboldt and Bonpland. They set out on an expedition to ascend the Peak of Teneriffe; at its base the trade wind was blowing strongly in its customary direction, but upon reaching the summit they found that they had actually penetrated through the lower stratum of air, and entered into the upper, and they now felt a strong wind blowing from precisely the opposite quarter.

While the tropical zone is in general distinguished by the regularity of its winds, we find the temperate regions, beyond the limits of the trade winds, the seat of perpetual conflicts between the equatorial and polar air-streams. Sometimes the upper current blows triumphantly across the Atlantic, and, laden with tropical moisture, descends upon our shores in fertilizing showers; and then, again, the polar under current, flowing in from the east, brings us serene skies and dry weather. Upon the various phases of these alternating conflicts depends the decision whether our winter is to be mild or severe, or our summer dry or wet; whether chilly blasts are to retard our spring, or genial breezes to accelerate the blossoming of our violets and daisies; whether our cornfields are to droop for want of rain, or to be refreshed by abundant moisture.

> What way does the wind come? What way does he go?
> He rides over the water and over the snow,
> Through wood and through vale, and o'er rocky height
> Which the goat cannot climb, takes his sounding flight.
> He tosses about in every bare tree,
> As, if you look up, you plainly may see;
> But how he will come, and whither he goes,
> There's never a scholar in England knows.

Yet in spite of the great irregularity which characterises the direction of the winds in our latitude, it has been ascertained that they have a preponderating tendency to veer round, according to the sun's motion; that is, to pass from north, through east, to south, and so on, round in the same direction from west to north.

In this direction they often make a complete circuit, or more than one in succession, occupying many days in doing so; but they rarely veer, and very rarely, or never, make a complete circuit in the opposite direction. For a station in S. lat., a contrary law of rotation prevails. This law, though more or less suspected for a long time, was first formally enunciated and explained by Dove, the celebrated Berlin meteorologist, and is known as Dove's law of rotation of winds.

In the polar regions, the winds are generally confined in their extension to a narrow space, so as frequently to blow from several parts of the horizon at once. Thus, in the icy sea between Spitzbergen and Greenland, ships may be seen sailing at the same time in opposite directions, or some of them becalmed, while others are driven along by a fresh gale. The cause of these local disturbances in the equilibrium of the atmosphere is the great difference of temperature above the ice fields, and on the open water, or resulting from light and shade. In Tajmur Land, the most northern promontory of Asia, Middendorff observed that as soon as a cloud passed before the sun, sudden gusts of wind immediately arose.

In all tropical maritime countries, the wind blows during a certain number of hours every day from the sea, and during a certain number towards the sea from the land; these winds are called the sea and land breezes. During the day, under the powerful rays of a vertical sun, the land becomes greatly heated, much more so than the sea; an ascending current consequently arises from the land, and to supply the place thus partially vacated, a body of cool air flows in from seaward, producing the sensible effect of a fresh breeze blowing from the sea, from about 9 or 10 o'clock in the morning till 3 or 6 o'clock in the afternoon. The sun then begins to lose its power, the land also begins to cool, and towards evening and during the night the land being a better radiator of heat than the water, it becomes colder than the sea. The heated column, therefore, now rises from the sea, and the cold horizontal flow is from the land, the sensible result being a fresh breeze to seaward, beginning at seven, and continuing till eight in the morning, when it dies away. When the heated column in either case reaches a certain height in the air, it turns over, blows along the upper region, and then comes down to supply the place of the descending current. During the summer, the sea breeze is very perceptible on all the coasts of the Mediterranean Sea, and even sometimes as far north as Norway. In the tropical regions, its regular occurrence is of the highest importance to navigation, as it favours the setting sail or the running of vessels into port. The refreshing sea air which it wafts by day over the sultry coasts is also one of the most agreeable meteorological influences of the torrid zone.

A similar phenomenon, which has been frequently observed in mountainous regions, is the hill and valley breeze, and it arises precisely from the same cause, namely, inequality of temperature setting in motion an ascending and a compensating current. Thus, after calm and warm days, a cold wind streams in the evening, and continues blowing during the night down the Munster Valley in Alsatia, into the plain of Colmar; and at the mouth of the valley of the Neckar, at Heidelberg, a cold air-current very perceptibly sets in in the evening during serene and wind-still weather. Mr. Darwin makes particular mention of a powerful hill and valley breeze which he observed in the ravine of Paypote, in Northern Chili. The winds in these lofty regions obey very regular laws; every day a fresh breeze blows up the valley; and at night, an hour or two after sunset, the air from the cold region above descends as through a funnel. In the Cordillera, the hill breeze sometimes rushes down the high mountain passes with such violence and icy coldness as to prove fatal to the travellers exposed to its icy blast. 'My guide,' says Mr. Darwin,[1] 'was passing the Cordillera with a party in the month of May, and while in the central parts a furious gale of wind arose, so that the men could hardly cling on their mules, and stones were flying along the ground; the day was cloudless, and not a speck of snow fell, but the temperature was low. It is probable that the thermometer would not have stood very many degrees below the freezing point; but the effect on their bodies, ill-protected by clothing, must have been in proportion to the rapidity of the current of cold air. My guide's brother tried to return, but he perished, and his body was found two years afterwards, lying by the side of his mule near the road, with the bridle still in his hand. Two other men of the party lost their fingers and toes, and out of 200 mules and 30 cows, only 14 mules escaped alive. Many years ago, the whole of a party are supposed to have perished from a similar cause, but their bodies to this day have never been discovered. The union of a cloudless sky, low temperature, and a furious gale of wind, must be, I should think, in all parts of the world, an unusual occurrence.'

Similar atmospherical conditions to those which cause the sea and the hill and valley breezes, warrant the belief that if on a still day the atmosphere of London were to be carefully observed in calm weather, it would be found that in the morning streams of fresh air are flowing in from the country round about the metropolis down all its suburban streets, to supply the place of the current which, heated by the vast city, rises up into the air from its centre.

The velocity of the wind is extremely various, from the gentlest breeze to the irresistible hurricane. A pretty good idea of its gradations may be formed from the following tables which are in use in the British and American navies. In the English scale, drawn up by Captain Beaufort—

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[1] 'Journal of Researches.'

0	denotes	Calm		
1	„	Light Air	Just sufficient to give steerage way.	
2	„	Light Breeze	With which a well-conditioned man-of-war under all sail and clean full would go in smooth water from	1 to 2 knots
3	„	Gentle Breeze		3 to 4 knots
4	„	Moderate Breeze		5 to 6 knots
5	„	Fresh Breeze	In which the same ship could just carry close-hauled	Royals and
6	„	Strong Breeze		Single reefs and top-gallant sails,
7	„	Moderate Gale		Double reef, jib,
8	„	Fresh Gale		Triple reefs, courses,
9	„	Strong Gale		Close reefs and courses
10	„	Whole Gale	With which she would only bear	Close reefed main-top-sail and reefed fore-sail
11	„	Storm	With which she would be reduced to	Storm staysail
12	„	Hurricane	To which she could show	No canvas

In the wind-table of the Smithsonian Institution which has been introduced in the American navy:—

Degree		Velocity (Sea miles per hour)	Pressure (Pounds on square feet)	Name
1	denotes	2	0·02	Very light breeze
2	„	4	0·08	Gentle breeze
3	„	12½	0·75	Fresh wind
4	„	25	3·00	Strong wind
5	„	35	6·00	High wind
6	„	45	10·00	Gale
7	„	60	18·00	Strong gale
8	„	75		Violent gale
9	„	90		Hurricane
10	„	100		Most violent hurricane

The famous Eclipse, the fleetest racehorse ever known in England, flew over the course at the rate of fifty-eight feet in a second, but he would have been far outstripped by the hurricane which rushes along with double or three times that velocity.

The wind is often very violent at a distance from the earth, while it is quite calm at its surface. On one occasion, Lunardi went at the rate of seventy miles an hour in his balloon, though it was quite calm at Edinburgh where he ascended, and continued so during his whole voyage. In the following cases, selected from many observations that have been made during balloon ascents in England, we likewise find the wind blowing with stormy violence in the upper regions of the atmosphere, while the anemometers at the meteorological stations below indicated but a very moderate breeze along the surface of the earth:—

	Geographical Miles per Hour	
	Balloon	Anemometer
June 26, 1863	9	2·1
July 21, 1868	6·3	2·2
Sept. 29, 1863	7·5	2·5
January 12, 1846	7	1·3

Though the storms of the temperate zone are generally far surpassed in violence and frequency by the tropical cyclones, yet in Europe also a hurricane wind sometimes rushes along with irresistible fury, and strikes terror into the heart of man. On land it unroofs houses, and lays whole forests prostrate, and along the coasts hundreds of wrecks annually bear witness to its destructive rage.

After a period of unusually warm weather, Vienna was assailed by a furious tempest on September 30, 1807, at one o'clock in the night. The strongest buildings were shaken to their foundations, and thousands of roof-tiles and chimneys flew down into the streets. Between three and six in the morning the storm attained its greatest violence, and then gradually subsided. The cupola of the dome of the Augustine Church was carried away, and seemed to have taken a complete turn in the air. An iron dial on the steeple of St. Michael's Church was rolled up like a piece of paper, and so many of the strongest trees in the Prater were broken or torn up by the roots that they were sold to the wood merchants for twenty-five thousand florins.

The coasts of Norway are exposed to the most dreadful gales, probably on account of the great difference of the temperatures of the sea and land, particularly in winter. According to Leopold von Buch[1] and Bedmar,[2] they howl along the steep fiords of Finnmark, and particularly at Kielvig, with such fury that no fire can be kept burning, and the houses would scarcely be able to resist them if they were not built very deep in ground, and had not, moreover, walls three feet thick. In Wardoehuus no one ventures to go out as long as they last, for fear of being blown into the neighbouring sea, whose waters, breaking into foam, and driven along by the blast, cover the whole coast with a dense cloud. These storms, whose direction is constantly from the north-west, are so very frequent that Herzberg counted 260 of them in twelve years, and no less than thirty-three in 1798.

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[1] Reisen, vol. ii. p. 92.

[2] Reisen, vol. ii. p. 159.

In Iceland gales of dreadful violence are likewise of frequent occurrence. While Professor Sartorius von Waltershausen was descending a steep mountain slope leading to the head of the Walfiord, the wind raged with such fury over the bay that the spray of the sea was driven upwards to a height of 2,000 feet. Sometimes clouds of volcanic dust, converting day into night, are raised by the gale from the lava and cinderfields of Hecla.

The memory of the 'Great Storm,' which in the year 1703 'o'er pale Britannia pass'd,' still lives together with that of the 'Great Plague' and the 'Great Fire.' This terrible tempest, the only one which has ever in England been the occasion of a Parliamentary address, or of public fast,[1] raged for an entire week without intermission, but was at its height on Saturday, November 27. Then, indeed, it seemed as if Eolus had let loose his winds to do their worst, and as if sun, earth, and heaven were torn and rent in one wild confusion. That the end of all things was come was very generally believed. 'Horror and confusion,' writes Defoe, 'seized upon all; no tongue can express it, no thought conceive it.' In London alone the damage done was estimated at a couple of millions. Everywhere the streets were strewn with the ruins of fallen houses, and for months and months after, the great city looked like a lot of miserable wigwams, so patched and cobbled was it with thatch, boards, tarpaulin, and old canvas. On the river raged an Oriental hurricane, aggravated by a 'bore,' such as that which at times sweeps up the Hooghly. The tide rose twenty feet above the usual marks. The vessels, torn from their moorings, were dashed against one another. More than a thousand craft of all sizes were crushed or sunk, and for days upon days the swollen river rolled up and down between the bridges burdened with bodies and floating fragments of wreck. Off the coast the elements raged with even fiercer wrath. Old Eddystone Lighthouse, built by Winstanley,[1] a quaint cumbrous top-heavy imitation of a Chinese pagoda, and consequently but ill calculated to resist the elements, was swept away like so much chaff. The fleet under Sir Cloudesley Shovel had but just returned from the Mediterranean, and was lying at anchor in the Downs. Upon it the full fury of the tempest broke, and scattered it in a moment. Six vessels of the line were totally lost, and several more driven ashore, while with them perished 1,500 men and officers of all ranks.

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[1] Lord Macaulay's 'Essay on the Life and Writings of Addison.'

In certain countries special winds are distinguished by local appellations. On the coasts of the Adriatic and Black Seas we find the dreaded Bora, a sharp, dry, and often very cold north-east wind, which generally arises with extreme violence, and then lasts for several days. Its name is beyond all doubt derived from the old Greek Boreas. The hurricanes of the tropics are hardly more terrible than the Bora on the eastern coast of the Black Sea, where it raves with particularly destructive fury at Nowo Rossiisk, a newly-founded Russian establishment at the head of a bay of the same name. This town, the site of which seems to have been very unluckily chosen, is situated with its two forts on the south-western coast of the bay. When the Bora blows with all its fury, the sentinels conceal themselves behind the breast-works; no signal can possibly be heard in the forts, no fire will burn, and whoever is surprised by the Bora on an open place is obliged to yield to its resistless force, and thrown down upon the ground. When the Bora rages in winter, the clothes wetted by the spray, which reaches the most distant houses, are in a few minutes frozen stiff upon the body, and sharp icicles are flung into the face, and make it bleed. When the cold is very severe the water drifted by the wind forms an ice-crust on the sides and deck of the ships, which, from this constant increase of weight, eventually sink to the bottom, as it is utterly impossible to take any measures for their safety.

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[1] 'The Sea and its Living Wonders,' Chap. VII., 'Marine Constructions,' p. 81.

On the Karst, the ill-famed arid mountainous district to the north of Trieste, the trees present a strange appearance, as towards the north and east they have few or no branches, and incline their tops to the south-west. The houses also, which are of a massive construction, have only dead walls towards the north-east, and their windows always face the opposite side—the country being exposed to the irruptions of a mischievous fury, who occasionally bursts forth from the solitary mountain ravines, and, howling over the naked plateaux, scourges the floods of the Adriatic into tumultuous waves. This fury—the dreaded Bora of the Karst—does not rage everywhere with equal violence, but chooses particular spots for the favourite scenes of her ill-humour. Thus the old Laibach-Trieste road from St. Peter to Divezza had to be abandoned, as the heaviest waggons were overturned, and men and horses carried away to a great distance by the Bora. Near Prewald, in the year 1805, a division of the Austrian army then on its retreat from Italy was surprised by a heavy Bora, so that it was impossible for the soldiers to continue to march, and many of them were killed without being pursued by the enemy.

To Professor M. Schön we are indebted for an interesting account of the violence of the Bora. In its rage it tears large edge stones from the roofs of houses, and snaps the thickest branches. The Bora which blew on January 14, 1871, moved with a velocity of 126 feet per minute, equal to a pressure of 33 lbs. on the square foot; and storms of still greater power have been known to occur. The Professor found that loaded railway waggons of a total weight of ten tons were alone able to maintain their balance against the assaults of this tremendous wind. The lighter passenger-cars were so fearfully shaken from one side to the other that the alarmed travellers left them at the next station, and preferred interrupting their journey to trusting their lives any longer to the mercies of the Bora.

On the Adriatic, the Bora produces a singular phenomenon, called the Fumarea or Spalmeggio, which is caused by the surface of the sea being swept into the air by the force of the wind, and forming a kind of fog.

In the south of France the Mistral plays the part of the Adriatic Bora, a generally dry north-east wind, which blows from the land over the Gulf of Lyons, sweeps over Minorca, and finally reaches Algiers. When very violent it lasts only one or a few days, but when of moderate strength it sometimes blows for several weeks together, to the great discomfort of the chilled inhabitants, and of the unlucky patients who have been advised to pass a winter in the genial climate of Provence.

The Mistral, which was unknown in the times of Julius Cæsar, is supposed to owe its origin to the destruction of the forests which covered the delta of the Rhone and the adjacent hills before the Roman Conquest. The stony plains of Le Craou, deprived of their ancient woods, become so intensely hot in the rainless summer that they frequently, like the Libyan desert, exhibit the spectacle of aerial refraction. The cold air from the snowy summits of the Alps then descends in furious gusts to fill up the void occasioned by the ascent of the heated air, and occasions the Mistral, which a popular verse reckons, along with the ancient parliament of the province and the inundations of the Durance, among the three plagues of the country.

Le Parlement, le Mistral, et la Durance
Sont les trois fléaux de la Provence.

The approach of the Mistral, which is confined to the coast districts, is announced by white cottony clouds (*balles de coton*) suddenly appearing on the serene sky; and as this very unpleasant wind blows on an average during seventy-eight days in the year at Toulon, eighty-four at Marseilles, eighty-five at Arles, eighty-eight at Aix, and ninety in the valley of the Durance, it may well be called a plague.

The high temperature of the deserts of Asia and Africa frequently occasions very hot and dry winds, which have given rise to many wonderful tales, for man is ever inclined to aggravate the convulsions of Nature by imaginary terrors. So much is certain, that though the breath of the Simoom or Khamsin—the dreaded winds of the Arabian waste, or the

Sahara—is not absolutely poisonous, it exerts a highly pernicious influence over all living beings that come within its reach. At its approach, the crystal transparency of the sky is veiled with a hazy dimness, occasioned by the sand of the desert whirling at a distance in the agitated atmosphere, but as yet no wind is felt. The camels, however, are conscious of its approach. They become restless and anxious, and appear overcome by fatigue. And now a light hot wind arises, blowing in intermittent gusts, like the laborious breathing of a feverish patient. Gradually the pantings of the storm grow more violent and frequent; and although the sun is unable to pierce the thick dust clouds, and the shadow of the traveller is scarcely visible upon the ground, yet so suffocating is the heat reflected by the glowing sand, that it seems as if the fiercest rays of the sun were scorching his brain.

The fiery purple of the atmosphere gradually changes to a leaden blackness; the wind becomes constant; the camels, snorting and groaning, stretch out their necks flat upon the ground, and turn their backs to the raging sandstorm. The travellers of the caravan pile up their water-bags, so as to screen them as much as possible from the thirsty breath of the Simoom, and, wrapping themselves up in their cloaks, seek a shelter behind chests or bales of merchandise.

A prolonged Simoom causes more fatigue to man and beast than all the other hardships of a desert journey, and brings new and intolerable sufferings to the traveller. Under the parching influence of the dry air, his lips spring open and begin to bleed; his tongue vainly longs for a refreshing draught; and, together with a raging thirst, an insupportable itching and burning invades the whole body, for the skin bursts in a hundred places, and the fine irritating dust penetrates into every wound.

Thus, though the old story of the whole army of Cambyses having been destroyed by the Simoom on its march to the temple of Jupiter Ammon, may be an exaggeration, there can be doubt that this dreadful wind has levied its tribute of death and misery on many a caravan.

In the desert between Khiva and Bokhara, at a station distinguished by the charming name of Adamkrylgan (the place where men perish), Arminius Vambéry was overtaken by one of these hot sandstorms, which he thus graphically describes:—

'As we approached the mountain, the Kervanbaschi and his people, pointing out to us a cloud of dust which seemed to advance towards us, told us to dismount without delay. Our poor camels, more experienced than ourselves, had already recognised the approach of the Tebbad (as this wind is called), and, after raising terrible clamour, they fell down upon their knees, stretching out their necks upon the ground, and trying to hide their heads in the sand. Behind their bodies, as behind a sheltering retrenchment, we had just time to crouch when the wind passed over us with a hollow murmur, and covered us with a thick coat of sand. The contact of its first grains seemed like a rain of fire. If we had been exposed to the shock of the Tebbad some twenty miles farther on in the depth of the desert, we should undoubtedly have perished. After its passage, the atmosphere became more thick and suffocating. Two of our poorest companions, whose provision of water was exhausted, had to be tied down flat upon the camel's back, as they were quite unable to keep their seat. As long as they could articulate a word their parched lips uttered only the monotonous exclamation, "Water! water! for pity, only a few drops of water!" Alas! their best friends refused to give them the smallest portion of the precious liquid which in the desert is life, and when on the fourth day we arrived at Mederma Bulag, one of these poor wretches was delivered by death from the torments of thirst.'

On the coast of Guinea, a remarkable easterly wind, called the Harmattan, prevails during the months of December, January, and February. It comes on at any hour of the day, at any time of the tide, or at any period of the moon, and generally lasts only a day or two, though it has been known to continue for a fortnight. There are generally three or four returns of it every season. It blows with a moderate force, not quite so strong as the sea breeze, but somewhat stronger than the land wind at night. A fog or haze is one of the peculiarities which always accompany the Harmattan. The gloom it occasions is so great as sometimes to render even near objects obscure. The sun, concealed during the greatest part of the day, appears only for a few hours about noon, and then of a mild red colour, exciting no painful sensation in the eye. Extreme dryness is another characteristic property of this wind.

No dew falls during the continuance of the Harmattan, nor is there the least appearance of moisture in the atmosphere. Vegetables of every kind are very much injured, the grass withers and becomes dry like hay, the branches of the trees droop, the leaves become flaccid, withered, and if the Harmattan continues to blow for ten or twelve days, are so parched as to be easily rubbed to dust between the fingers. The natives take this opportunity of the extreme dryness of the grass and young trees to set fire to them, especially near their roads, not only to keep those roads open to travellers, but to destroy the shelter which long grass and thickets of young trees would afford to skulking parties of their enemies. A fire thus lighted flies with such rapidity as to endanger those who travel. In this situation, a common method of escape is, on discovering a fire to windward, to set the grass on fire to leeward, and then follow the fire.

The parching effects of the Harmattan are likewise evident on the external parts of the body. The lips and nose become sore and even chapped, and there is a troublesome sensation of prickling heat on the skin. If the Harmattan continues four or five days, the scurf skin peels off first from the hands and face, and afterwards from the other parts of the body if it continues a day or two longer. A very remarkable peculiarity of the Harmattan is its salubrity, for though so very prejudicial to vegetable life, and occasioning such disagreeable parching effects on the human species, yet on some parts of the coast at least it is highly conducive to health. According to Mr. Norris, a gentleman who had frequent opportunities of observing its singular properties, those labouring under intermittent fevers generally recover in a Harmattan.

Dr. Livingstone describes a similar hot wind which blows over the Kalahari desert from north to south. It feels somewhat as if it came from an oven, and seldom blows longer at a time than three days. It resembles in its effects the Harmattan, and at the time the missionaries first settled in the country, half a century ago, it came loaded with fine reddish coloured sand. Though no longer accompanied by sand, it is so devoid of moisture as to cause the wood of the best seasoned English boxes and furniture to shrink, so that every wooden article not made in the country is warped. The wind is in such an electric state that a bunch of ostrich feathers held a few seconds against it becomes as strongly charged as if attached to a powerful electrical machine. When this hot wind is blowing, the peculiarly strong electrical state of the atmosphere causes the movement of a native in his kaross to produce therein a stream of small sparks.

In Italy and Spain, the Sirocco and the Solano partake of the character of the Simoom. 'I opened my door at eight in the morning,' writes Brydone from Palermo, 'without suspecting there was any change in the temperature, when all at once I felt a burning impression upon my face, like the air from a hot oven. I closed my door, exclaiming to Fullarton that all the atmosphere was on fire! At this moment the thermometer in the open air marked 111°.'

The hot breath of the Sirocco produces the utmost languor and depression of spirits. It renders the least exertion irksome, and the irritation it causes in persons with excitable nerves is said to be a frequent cause of bloodshed and murder.

The Fön, a warm southerly wind which frequently crosses the Alps, is generally considered as a continuation of the Sirocco. The atmospherical phenomena to which it gives rise are finely described by Tschudi.

On the southern horizon light beautifully-tinted streams of vapour make their appearance, and settle on the mountain tops. The sun sets dimly in a deep red sky, and the clouds glow for a long time after with the liveliest purple. The dull moon has a reddish halo. The atmosphere attains the highest degree of transparency, so that the distant mountains which are clothed with bluish violet tints appear much nearer. With a few heavy gusts which at first are sharp and cold, particularly in winter, when it sweeps over enormous snow-fields, the Fön announces its arrival, which is suddenly followed by a deep stillness of the air. The succeeding warm floods of the Fön then burst with violence into the valleys, and often swell into dreadful hurricanes, which for several days set all Nature in an uproar, hurl trees into the abyss, tear rocks from the mountain slopes, cause the torrents to overflow, carry away the roofs of houses, and become the terror of the land. On the Alpine animals the Fön produces the same enervating effects as the Sirocco in Italy. The chamois retreat to the northern side of the mountains, or seek a shelter in the deep gorges. No bird is to be seen in the forests and the fields. Man participates in the general uneasiness, and feels languid and depressed.

During a violent Fönstorm all the fires are carefully extinguished, and in many valleys inspectors, appointed for the purpose, hurry from house to house to convince themselves that none have been left burning, for the houses, being built of wood, a single spark might produce a disastrous conflagration.

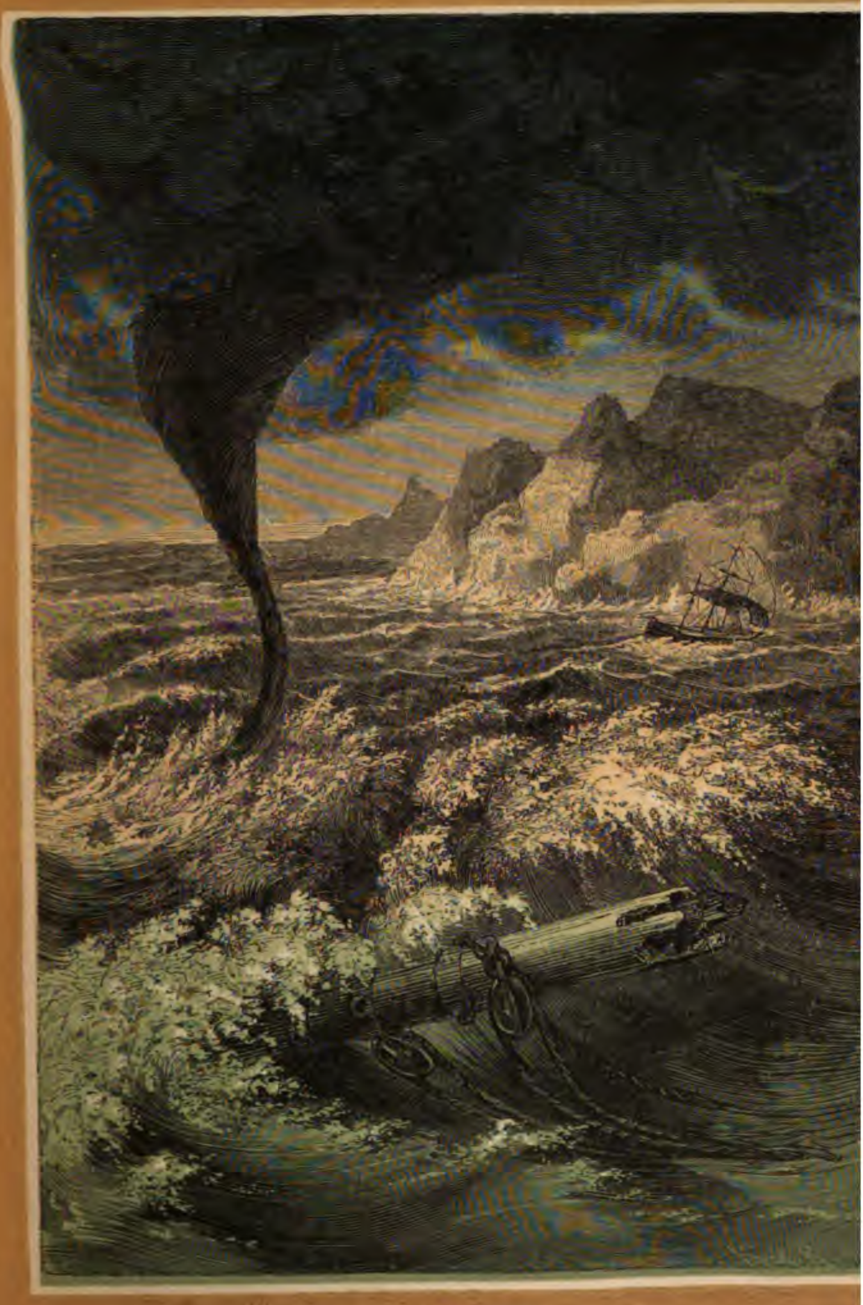
Nevertheless, although the Fön is more dangerous than any other Alpine wind, its arrival in spring is welcomed with joy. In the whole mountain region it melts enormous ice and snow masses, and suddenly changes the wintry aspect of the country. It is the real herald of spring, and does more in twenty-four hours to remove the trophies of winter than the sun in a fortnight, as the old and hardened layers of snow, on which the sun acts but slowly, are unable to resist its warm breath. In many of the higher valleys there would, in fact, be no spring at all without the Fön, and in many of the plains the grapes would not ripen in autumn without its assistance. If it did not from time to time sweep away the newly formed accumulations of snow there would even be no summer and no life in the high Alps, but probably only constantly increasing snowfields. In the canton of Uri, where it blows very frequently, the people have to thank the Fön that the glaciers do not reach lower down into the valley, and that the Alpine meadows are sooner available for pasture than in most other districts at an equal elevation.

CHAPTER VIII.

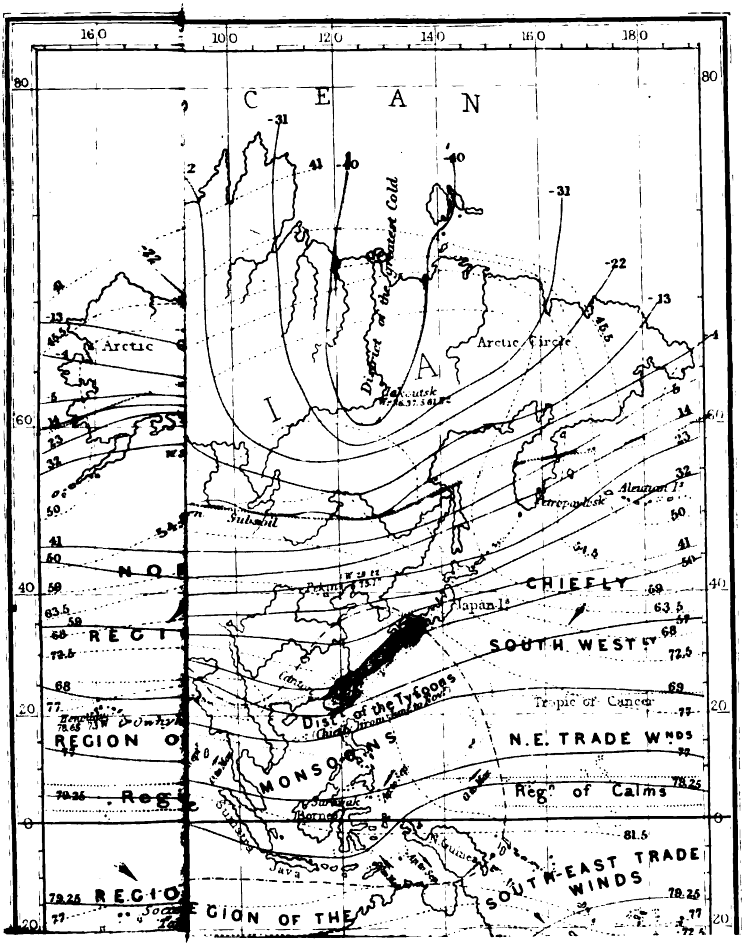
WATERSPOUTS—LANDSPOUTS—TORNADOS.

Waterspouts—Sandspouts—Frequently Observed in Sultry Deserts—Landspouts—Their Form Described—Their Size and Velocity—Often attended with Electrical Phenomena—Suction of Air within the Spout—The Destructive Effects of Large Landspouts near Hainichen in Saxony (1800), Riga (1872), Palazzolo (1872), Ossonval (1822)—Inoffensive Character of Waterspouts—The Seas where they are mostly seen—Various Opinions as to the Origin of Weatherspouts—The Tornados of the United States—The Tornado of Newhaven (1839), of New Brunswick (1835), of Mayfield—Enormous Velocity and Power of the Gyratory Motion of Tornados—Great Loss of Life occasioned by the Tornado of Natchez (1840)—The Spout of Calcutta (1838).

WHILE traversing the wide ocean, the seafarer meets with few phenomena of a more awful or mysterious nature than the waterspout. His ship is becalmed, the sea is smooth like a mirror, the air sultry hot, when suddenly a cloud is seen to descend in the form of an inverted cone, and at the same time a column rises out of the water, and whirls upwards with a hissing noise, until it unites with the funnel-shaped termination of the clouds. The sea seems to stream towards the sky, and the mariner is seized with terror at the sight; for he fears that the monstrous apparition may draw the ship into its vortex as it approaches, and plunge it into the abyss. In his distress he fires a cannon against it, and lo! ere it reaches the vessel, the dreaded column detaches itself from the sea, and disappears in the cloud above. Rain, accompanied by thunder and lightning, now pours in torrents from the cloud, and with new surprise the mariner finds that the large drops consist of sweet water, unmixed with the brine of ocean. He thanks Providence when finally the wind rises and carries him away unhurt from the fearful spot.

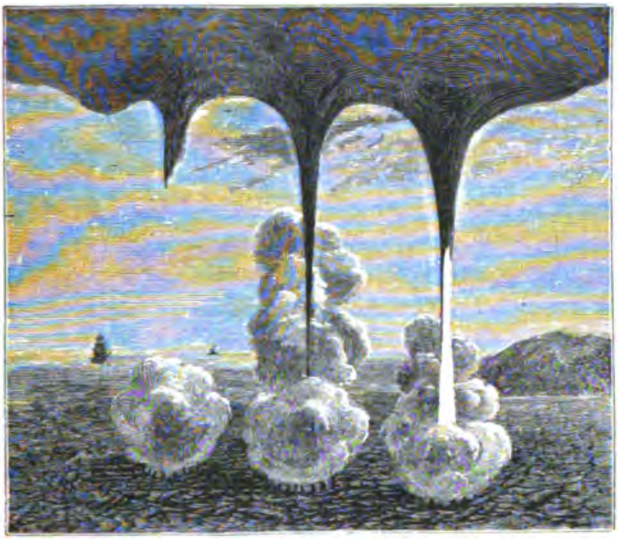


WATERSPOUT.



which in the hot season frequently

Similar phenomena also take place on land. As on the ocean, the sudden upwhirling of a watery column excites the mariner's wonder and dismay, sandspouts often rise in high rotatory columns from the parched plains. In the African desert Bruce frequently saw large pillars of sand, sometimes advancing with great rapidity, and on other occasions with a majestic slowness; and Stephenson repeatedly observed in Bengal rapidly gyrating sand columns of a colossal size. Humboldt tells us that in the American Llanos, during the dry season, the dust of the savannah ascends in mighty whirls, and glides over the desert plain. The glowing sand suspended in the air increases the sultriness of the atmosphere, and may even become dangerous to the traveller whom it happens to overtake; for, seizing him with irresistible violence, it carries him along in its embrace, and then hurls him senseless to the ground. Tschudi also describes the huge sand columns on the Peruvian coast, which, when a strong wind blows, rise like waterspouts to a height of eighty or a hundred feet.



WATERSPOUTS.

Mr. T. Belt gives the following account of the rotatory dust columns of Australia, which in the hot season frequently overturn the light tents of the gold-diggers. 'The dust and the leaves they carry along with them distinctly show their spiral movement upwards. Sometimes they stand still, but generally they advance with a regular horizontal movement. Clouds of dust envelope their foot, from which they rise to a considerable height, frequently deflected by upper air-currents from their vertical position. They are particularly frequent in the treeless plains, where the rays of the sun are very powerful.[1] But neither the sea nor the desert is the only scene where large gyratory columns of water or sand make their appearance; for the phenomenon of the landspout sometimes invades the highly cultivated districts of Europe on such a scale, and with such terrible effects, as to be ranked among the great catastrophes of nature.

Landspouts are commonly described as enormous funnels or cones with the point downwards, or as columns ascending to the skies in a somewhat curved or oblique direction. The form of the waterspouts, which, from the density of their contents detaches itself sharply from the adjoining atmosphere, might in many cases be compared to a gigantic hour-glass. Sometimes the central part of the waterspout remains invisible; and then the phenomenon has the appearance of two distinct cones with their apices directed towards each other. In other cases the meteor has no foot, and then it has been compared to a horn projecting from the cloud and descending in a point. Sometimes the formation of the foot precedes that of the cloud; in other cases, the contrary takes place, or both make their appearance simultaneously. The foot of the waterspout is generally surrounded by dense mists and a circle of small curling waves; the lower end of the landspouts by clouds of dust.

According to Horner, the waterspouts have a diameter of from 2 to 200 feet, and and a height of from 30 to 1,500 feet; but landspouts of far more considerable dimensions have been observed. From the distance at which they were seen, Oersted calculates that in some cases their height could not have been less than 5,000 or 6,000 feet. All spouts generally move onwards in a horizontal direction, with a rapidity varying from that of a pedestrian to the enormous velocity of 4,000 feet in a minute. Completely stationary spouts are very rare; in fact, the only instance known is that which occurred at Blanquefort, near Bordeaux, in the year 1785. Frequently the several parts of a spout do not move forward alike, so that the inclination of their axes often changes. Their course is sometimes straight forward, sometimes crooked, rarely in zigzags. Sometimes landspouts have been known to bound upwards from the earth, and, after traversing the air for some distance, to descend again upon the ground like some monstrous beast of prey darting upon its victim with prodigious leaps. A gyratory or spiral motion, frequently of extreme violence, takes place in most spouts. Very frequently the air around rushes from all sides towards the foot of the spout, as is plainly shown by the direction of the prostrated corn, or of the uprooted trees, after the scourge has passed.

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[1] T. Belt, 'An Inquiry into the Origin of Whirlwinds,' 'Philosophical Magazine.' 1859.

Spouts are often attended with electrical phenomena. Of the 116 cases mentioned by Peltier, 41 emitted lightning and thunder, and 14 were accompanied by snow and hail. Heavy showers of rain are frequently mentioned in descriptions of spouts, and it is very remarkable that even when to all appearances the water of the sea rises to the skies, the rain that follows is completely sweet; thus proving that it is formed of condensed vapours, and not of sea-water raised by aspiration. Several spouts frequently occur at the same time. Thus, Peltier mentions three observations where seven waterspouts, and one where six of these meteors were seen at once. Not seldom, also, several spouts appear in succession.

We have, unfortunately, but few direct observations of the changes in the pressure of the air which accompany the phenomenon of spouts. In some instances, however, a considerable fall of the barometer has been found to precede their appearance.

At Rouen, on August 19, 1845, the glass stood at noon at 757·25 millimetres, and about one at 740·91, so that it had fallen 16⅓ millimetres; about 15 minutes later a spout uprooted at Houlme, 8,000 metres from Rouen, 180 large trees in a few seconds. Half an hour before, this same spout had destroyed three cotton mills and killed a number of workmen at Monville (15,000 metres from Rouen). The ruins of these buildings fell down about one o'clock in large quantities in the environs of Dieppe, so that in less than 30 minutes they had been transported to the vast distance of 32,000 metres. Another instance of a fall of the barometer is mentioned by Oersted. Near the town of Eu, it had stood during three days at 28 inches 5 lines, when on June 16, 1775, at seven in the morning, it suddenly fell about 2¼ lines, upon which a spout followed at eight o'clock. At noon the barometer had again risen to its former height.

A kind of suction, indicating a rarefaction of the air within the spout, has more than once been remarked; thus we read of roofs and ceilings torn upwards, or even of floors wrenched open.

A loud noise, like the sound of carriages rolling over a stony road, or like that which is heard during heavy hailstorms, or like a blustering piping wind, is often mentioned as accompanying spouts. Sometimes, however, no sound is heard, and the noise is said to diminish when a spout passes from the land to the water.

A sulphurous smell (ozone ?) has also been perceived in some cases; and spouts are mentioned which emitted a phosphorescent gleam, or in which globes of fire and lightning were seen.

But it is chiefly by its prodigious mechanical effects that the phenomenon of a large landspout makes an overwhelming impression on most observers; and this, together with its sudden irruption and short duration, is probably the cause why we have so little precise information on points of a greater meteorological interest.

These effects are confined to the comparatively narrow space traversed by the foot of the column. Light objects are raised high into the air. Letters, and even branches of trees or planks, have repeatedly been transported to a distance of many miles, and green leaves and boughs have been seen to fall again upon the earth covered with a crust of ice.[1]

The following instances will serve to give an idea of the destructive power of large spouts:—On April 23, 1800, at about four o'clock in the afternoon, a long black column was seen to descend from a thick cloud, about a couple of English miles from the small Saxon town of Hainichen, the birthplace of the poet Gellert. The column, which was about sixty paces broad, moved with incredible rapidity over a space of about five English miles. All that it encountered on its path was destroyed, while a complete calm reigned along its sides; for among others, a peasant woman of Dittersdorf saw from her window a neighbouring barn suddenly fall in, while she herself felt no wind at all. In Arensdorf, where the column first touched the ground, roofs were torn from the houses; but the destruction was far greater at Dittersdorf, where, among others, a large massive building was destroyed, with the exception of its left wing, which was shoved out of its place. The walls were rent, and even the vaults were unable to withstand the violence of the spout. Proceeding on its path of ruin, the whirlwind next destroyed five houses, and then forced a passage through a wood; all the trees it met with were either uprooted or mowed down as with a scythe, so that almost instantaneously a broad avenue was swept through the forest. At Etzdorf, the spout at length spent its force, having first raised a man and two horses from the ground, and thrown the former into a ravine, the latter into a brake on the roadside.

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[1] Espy, 'Second Report on Meteorology,' p. 16.

On May 23, 1872, the environs of Rg a were devastated by a tremendous spout. After a short thunderstorm, a dark cloud ascended from the south-west, and was at first supposed to be the smoke of some buildings set on fire by the lightning; but it was soon seen to advance from SSW. to NNO., maintaining its dark colour and its original form, being broad above, and tapering to a point below. Several persons were attending the funeral of a child in a churchyard, and seeing the cloud advance, endeavoured to reach the chapel, which was about fifty paces from the grave, when suddenly they were lifted up by the spout, and hurled far away. Some were rolled along over the ground like balls, and others were immediately killed by the stones and trees that fell upon them. A girl, twelve years old, was swept away by the whirlwind, and dashed with such violence against the ground that her skull and shoulders were fractured. Three of the company assembled in the churchyard were killed at once, and five severely wounded. It is almost impossible to give an idea of the tremendous power of this spout. The strongest trees were unable to resist it, many being torn up by the roots, others broken through in the middle and scattered about in all directions. The strong stone wall which surrounded the churchyard seemed as if it had been battered by artillery. Large slabs from two to three feet thick were hurled to a distance of sixty feet. A horse, fastened outside the churchyard, was thrown, along with the cart, over the wall; the horse escaped unhurt, but the cart was broken to pieces.

About twenty-five Italian miles to the west of Syracuse lies the small town of Palazzolo, well known to archæologists by the remains of its ancient Grecian edifices. In November, 1872, a landspout swept over this interesting little city, with a violence fortunately unexampled in our temperate zone. The ravages it caused are thus described by an eyewitness in the 'Gazetta di Siracusa':—

'Where but a few hours since stood the new theatre and well-built houses, the deplorable aspect of a heap of ruins now shows itself to the terrified spectator. Five minutes of an indescribably furious whirlwind have sufficed to render this whole part of the town uninhabitable, and to plunge hundreds of families into the deepest distress. No one remembers a similar catastrophe; even the earthquakes have never caused such devastation. Houses demolished down to the very foundation, walls rent and leaning forwards, roofs swept away, vaults fallen in, balconies torn off, windows smashed, trees uprooted, and in all the remaining town not a dwelling uninjured. In that part which has suffered most, the façade of the Church of San Sebastiano has partly been torn away from the back of the edifice, so that the whole has to be rebuilt; the walls of a convent of nuns have been levelled to the ground, only a small part of the theatre remains standing, and close by two large houses have buried more than ten persons under their ruins. The streets are completely blocked with stones and rubbish of all kinds. Of twenty-five hectolitres of corn that were kept in a magazine not a vestige remains.

'The registers of the public offices have disappeared; a volume has been found here and there at a distance of many metres. The iron bars of a balcony have been twisted together like a skein of thread; the column of a palace has been pushed forward six inches; everywhere destruction and confusion. The corpses which are successively dug from out of the ruins are collected in a stable. Most of them are only in their shirts, having been surprised by the catastrophe while sleeping. Here also the pathetic mixes with the horrible. A father, pressing his little child to his heart, both with fractured skulls; two brothers embracing each other in death; a young man, a person in office, his spectacles still before his eyes, surprised by death while writing. Many can no more be recognised; the whole number of those that have perished amounts to thirty-two.'

A huge spout which on July 6, 1822, traversed the plain of Ossonval, about fifteen miles from Boulogne and Saint Omer, seemed to be hanging down from a heap of clouds. It formed a cone thirty feet high and twenty-five feet in diameter, with its apex downwards, and gyrated with considerable rapidity. Sometimes it bounded upwards with a report like that of a cannon, leaving the mark of a large circular cavity in the ground. Its path was marked by devastation; it hurled trees to a distance of many hundred paces, destroyed thirty-two houses at Waternestre, and eighteen at Arbor. Constantly rotating on its axis, it leaped over the ground like a ricochetting cannon-ball, scattering fire and sulphurous fumes with a dreadful noise. No lives were lost. After having lasted above an hour, the spout suddenly dissolved, the atmosphere became calm, and the thunder which had been rolling on all sides ceased.

Fortunately all landspouts are not equally formidable and destructive, for in most cases those of which an account has been published confined their ill-effects to the dispersion of hay or corn stacks, to the breaking of small trees, or to the fright occasioned by their sudden invasion. A great number besides are so small and inoffensive as to remain entirely unnoticed.

Waterspouts seem to be harmless, notwithstanding their threatening appearance. We have numerous accounts of the phenomenon from all seas, except the Polar Ocean, where it has never been observed, and in none of the cases mentioned was any serious damage done to the ships that saw the dreaded meteor advance upon them. Possibly, however, some vessel that has been lost, and never afterwards heard of, may have been engulfed by a formidable waterspout.

Waterspouts are particularly frequent in the belt of calms, and never make their appearance within the range of the trade winds. From a great number of cases, Kämtz concludes that they more especially show themselves in the vicinity of high and steep coasts. They are often mentioned as occurring on the coast of Guinea, in the Straits of Malacca, in the Mediterranean, and the Red Sea. They have also been frequently noticed in the Channel, and in the Gulf of Finland.

The origin of spouts is still a matter of controversy. Kämtz assumes that they are due principally to two opposite winds, which pass by the side of each other, or to a very high wind which prevails in the higher regions of the atmosphere. Peltier, and many others, ascribe to them an electrical origin; while, according to Espy, they are merely ascending air currents, which owe their energy to the condensation of the aqueous vapour they carry along with them. Where such differences of opinion prevail among good authorities, we have reason to conclude that the mystery of the formation of spouts is still unsolved.

The land tornados of the United States form, by their dimensions and their dreadful mechanical effects, a transition from the spouts to the cyclones, exhibiting the phenomena of the former on a gigantic scale, and emulating the latter by their widespread fury. The width of their path along the surface of the earth amounts in some cases to as much as an English mile; its length varies from two to eight hundred miles. The rapidity of their progressive movement is very great, as they advance on an average at the rate of thirty-seven miles per hour, but it is far surpassed by the whirlwind velocity which takes place within their vortex, and imparts to it its irresistible power.

While the whole tornado from the beginning to the end of its disastrous career often lasts several hours, the destruction it effects on each single spot that it traverses is generally completed in less than a minute, and often as instantaneously as that of the earthquake shock or the lightning flash. Like a monstrous cloud, white as a snowstorm impelled by a furious gale, and internally in the most violent commotion, the tornado of Newhaven (July 31, 1839), suddenly appeared and overwhelmed the spectators with torrents of rain, 'one shock, one crash, and all was over.'[1] Almost every tree which it had met with on the open field was uprooted or broken; six houses, and a number of sheds, were totally destroyed, and wherever the hurricane gust had passed, it traced one uniform line of ruin. The famous hyperbole of Cæsar, 'I came, I saw, I conquered,' was in this case a literal truth.

The effects of tornados distinctly show that they are produced by an ascensional and centripetal motion of the air. The position of the prostrate trees regularly indicates that from all sides the air must have streamed towards the foot of the tornado, and the ascensional air current could very often be ascertained by the various objects it carried high up into the clouds, and which afterwards fell down again upon the earth at a vast distance.

The tornado which traversed the town of New Brunswick on June 19, 1835, may be cited as a remarkable instance of this centripetal motion. From a steam-vessel on the Rariton River, Professor Beck witnessed its original formation. A dense low cloud spread itself at some distance like a dark curtain, sank downwards in its centre in the form of a funnel, or of an inverted cone, and gradually joined another cone, the basis of which apparently rested on the earth. In a few minutes, however, this distinctly double cone transformed itself into a column expanding at the upper end, and resembling a volcanic eruption. These columnar and conical forms alternated several times. The tornado prostrated or swept away all the movable objects it met with on its path, which was from 200 to 400 yards wide. The trees which it seized one after another within its vortex were felled in the direction along which it moved, while those on both sides were always directed towards some point through which its axis had passed. Houses were unroofed, and in some the floors were wrenched open; in others, the walls were thrown down outwards as by an explosion. Two facts, ascertained by Mr. Espy and confirmed by Professor Bache, prove the existence of an ascensional motion. In a house which had been exposed to the vertical action of the tornado, a cloth was torn from a bed and forced into a crevice into the southern wall, which afterwards closed and held it fast. A towel was fixed in a similar manner in a crevice of the northern wall. In some cases, blockhouses were completely raised from their foundations. Beams and spars were torn from a house and cast to a distance of 400 yards. The tornado lasted but a few seconds on each spot which it touched. On one farm the whole damage was completed, according to the proprietor's declaration, while he was walking from the front to the back of the house, so that a perfect calm reigned when he reached the back gate; meanwhile, the building had been unroofed, and the neighbouring trees cast down. The noise which accompanied the phenomenon is described by all witnesses as dreadful, and might be best compared to that of a great number of heavy waggons rumbling over the pavement. Every object along its path was covered with mud on the side from which it came; the house looked as if bespattered with mortar, and the men were completely disfigured with dirt. Four different places were observed where all the prostrated trees pointed with their summits towards a common centre. Espy estimated the visible height of the tornado at about an English mile, and in his opinion all the phenomena agreed in proving a movement of this external air flowing from all sides towards the centre of the tornado, and an ascensional movement within.

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[1] Denison Olmsted in 'Silliman's Journal.'

The following example, selected from a list of thirty-three tornados, compiled by Mr. Loomis ('Silliman's Journal,' xliii. p. 298), gives an idea of their enormous power. The tornado of Mayfield, Ohio, threw down a number of trees from two to four feet thick, and raised several buildings completely from their foundations. A boy eleven years old was thrown to a distance of 150 yards through an open window, without suffering any greater injury than a slight bruise on his face. On looking back he found that the blockhouse, a large building two storeys high, had disappeared. It had been completely raised into the air and carried away to a distance of sixty yards; the upper part was scattered about in all directions, and some planks of the flooring were even carried away as far as seven or eight miles. The fact that planks with rounded edges were driven obliquely through the turf into the wet clay soil to a depth of from twelve to eighteen inches, and some with sharp edges even two feet deep, bears witness to the enormous velocity of the gyratory motion. Experiments with oaken boards, which were shot into the ground from a six-pounder, led Mr. Loomis to the apparently well-founded conclusion that the centripetal whirl of the tornado must have had the enormous velocity of 18,200 metres in a minute, equal to that of a shot from a gun of that calibre. The progress of this tornado was marked by an enormous column of a deep yellow brown colour, like smoke, quite dark below and lighter above. On crossing the Chagrin River it seems to have raised a great quantity of water, for on the eastern bank distinct signs of a considerable rise of the river were found. It did not sweep uniformly over the ground, but sometimes overleaped spaces of about half a mile, where it marked its passage through the air by the breaking of the highest trees at a distance of from twenty to forty feet above the ground. Similar bounds, such as some fabulous leviathan might be supposed to make, dealing destruction wherever it planted its huge foot upon the ground, and leaving the intermediate spaces undisturbed, are so frequently mentioned in the description of tornados, that alternating outbursts and interruptions or diminutions of their devastating power may be considered as a rule.

Their terrific violence not only shows itself in the raising of buildings from the ground, or in the uprooting of centenary trees, but also in the vast distance to which they carry objects through the air. Deal boards or shutters, and window-frames, have not seldom been transported by the whirlwind many miles away from the scene of destruction.

It is remarkable that in spite of their prodigious power, the tornados generally occasion no great loss of life, for with the exception of the tornado of Natchez, in the State of Mississippi (May 7, 1840), the tornados described by Mr. Loomis only caused on an average the death of one person. At Natchez extraordinary circumstances took place, for by far the greater number of the 317 victims of the catastrophe were drowned in the river, where the tornado sunk in a few seconds two steamers and sixty flat-bottomed boats. Altogether this tornado seems to have been one of extraordinary fury. Nearly nine inches of rain fell, along with enormously large hail-stones. Trap doors and a desk fastened with three locks were torn open as by an explosion. A tin plate and a window were carried to distances of twenty and thirty miles.

The spout of Calcutta (April 8, 1838), which on its march of sixteen miles killed no less than 215 persons, wounded 233, and destroyed at the same time 1,245 Indian huts, must therefore be considered as much more disastrous than any of the American tornados. The chief cause of its dreadful effects seems to have been its very slow progress, so that its local duration amounted to from four to seven minutes, while in the American tornados it rarely surpasses a minute. The rapidity of the wind within this spout was so enormous that a bamboo cane was driven through a mud wall five feet thick and clothed on both sides with brick. A six-pounder, says the editor of the 'India Review,' could hardly have produced a greater effect.

CHAPTER IX.

FOGS.

Evaporation—Point of Saturation of the Air with Moisture—The Formation of Fogs—London Fogs—Lines by Archdeacon Butler—Effect of a London Fog (Dec. 1873) on Horned Cattle—John Evelyn's Description of a London Fog—Dense Fogs over the Banks of Newfoundland—In Behring's Sea—Fogs produced by the Arctic Icefields and Icebergs—Fogs on the Peruvian Coast—Number of Foggy Days in various parts of Europe—Fogs in the Alps—Picturesque Effects of Fog—Day Fogs—The Höhrauch—The dry North American Fog—The Caliña—Obscuration of the Atmosphere by Volcanic Eruptions—Extraordinary Dry Fogs of the Years 526, 1783, and 1830 attributed to Nebulous Planetary Matter—Blueness of the Sun observed in Various Places—A Lesson of Humility.

THE ocean is the source of all life on earth—the colossal reservoir which provides all animated nature with the water necessary for its existence. Without the sea, all land would be a naked waste—a dreadful desert of sand and rock. It is the ocean which fills our granaries, adorns our gardens, feeds our flocks, and spreads the green canopy of our forests. It scatters fruits without number over the earth, for the nourishment of unnumbered creatures; if its urns were to be exhausted, death alone would reign on earth, and one common grave devour all living things. The sun has had his worshippers among the people of ancient days; but the sea was equally deserving of pagan homage, for without the sea, no human eye would have been dazzled by the great luminary's light. The warmth of the sun is indeed a prime necessity of life; but warmth requires the co-operation of moisture to awaken and maintain life, and this moisture is derived from the inexhaustible stores of the sea. The sun and the ocean, however, are still in need of a third auxiliary to enable them to scatter plenty over the smiling land; in vain would the sun dart forth his enlivening beams, in vain the ocean be filled with floods without end, if the atmosphere were not ready to absorb the exhalations of the sea, and to convey them on the wings of the wind far into the interior of the continents. Thus, every raindrop that irrigates our fields, every mist that obscures the air, is the product of the grand and harmonious action of the sun, the sea, and the atmosphere.

The evaporation of water is a phenomenon which must strike even the most careless observer. Everywhere the humidity of winter disappears from the ground after a few days of warm and serene weather. The stones moistened by a summer shower, the plants dripping with morning dew, are dried up after a few hours of sunshine.

The evaporation of water into the air is confined entirely to the surface, and hence it is always proportional to the surface exposed to the action of the air. Accordingly, observation shows that in maritime countries, and in marshy situations, in the neighbourhood of lakes, rivers, and over the surface of the sea, the evaporation is much greater than in inland countries and dry situations.

It is found that evaporation is greatest in hot weather; whence it must depend, in some degree, upon the temperature of the air.

There are, however, several circumstances which affect the quantity of vapour rising from water, even at the same temperature. Thus, we find that evaporation is least in calm weather, increases when there is wind, and is greater in proportion as the wind is stronger. The air, however, can only contain a certain quantity of aqueous vapour, which is constantly varying with its temperature. When its warmth increases, its capacity of retaining moisture in the invisible form of aqueous vapour increases; when there is a decrease of its temperature we find a proportional decrease in the quantity of aqueous vapour which it is able to retain.

The point of extreme atmospherical moisture is, therefore, as fluctuating as the capricious winds, or as the rise and fall of the barometer. In winter (and that is generally the case) the air, though containing but a comparatively small quantity of aqueous vapour, may thus be apparently more moist or nearer its point of saturation than in summer, when it is laden with a far greater quantity of invisible water. Evaporation may, in the latter case, be still proceeding with great activity, while in the former it is nearly reduced to a standstill. In the months of November and December the air seems generally more damp than in July, when it actually contains more than double the quantity of water.

Over the surface of the ocean the air is generally at all seasons and in every latitude near its point of saturation. On land the degree of its moisture depends chiefly upon the nature of the soil, the seasons, the direction of the wind, the distance of the sea, and the height above its level. When the temperature of a warmer stratum of air is so far cooled that the quantity of aqueous vapour it contains exceeds its actual point of saturation, this excess of moisture condenses, and either assumes the form of dew, or becomes visible to the eye in the form of a fog or cloud.

Fogs chiefly form over seas, lakes, rivers, and damp countries, particularly in autumn, when the ground is still comparatively warm, and the contiguous air strata, which are saturated with moisture, ascend into a colder atmosphere. On damp meadows, wreaths of fog are frequently seen to arise after sunset, even in the hottest months; but its formation is generally more abundant towards morning. In winter the rivers smoke because the air which is in contact with the warmer water acquires a higher temperature than that of the superjacent strata, and parts on rising with the vapours it had absorbed.

Fogs may also be caused by a colder air current descending upon a sheet of water or damp ground, and mixing with the warmer and moister atmosphere above it. In countries where the air is generally damp, and subject to frequent and rapid changes of temperature, fogs are of frequent occurrence; as, for instance, on the coasts of north-western Europe, which faces the moist breezes of the Atlantic.

The fogs of London, which, from their density and the intermingled particles of smoke, acquire a peculiarly dull, funereal tinge, have long enjoyed a proverbial celebrity. Not a year passes over the great metropolis without some days of intense fog, whose dark Cimmerian gloom is well expressed in the following lines:—

> Darkness upon the land! midnight at noon!
> Day without sunshine! night without a moon!
> Rayless eclipse! The tribute of the sky
> When He, the Lord of Nature, deigned to die!
> A starless void! A deep and awful gloom
> Fraught with strange fears, and herald of the tomb;
> Such, once before, on hardened Pharaoh lay,
> And filled his royal Memphis with dismay;
> Hid was the sun, the stars refused their light,
> And Egypt's noontide blaze was quenched in night.
>
> *Written by* ARCHDEACON BUTLER *during an intense London fog*

From December 8 to 14, 1873, London was enveloped in a misty shroud of almost unprecedented density, which entirely stopped the traffic on the river and the business in the docks. On the 12th about noon, the black veil cleared up a little, so that objects could be indistinctly seen at a few paces distance; but towards evening thick fog clouds rose again from the marshes of the Thames, so that no gas-lights could be distinguished in the streets, and the few cabs and omnibuses which ventured out had to be escorted by torch-bearers, and could only move step by step. The fog-signals exploding without intermission at the railway stations, and the dismal shrieks of the fog-horn, served to render the gloom still more melancholy. Many lives were lost; at Wapping, two men walked into the river down the boat-stairs and were drowned. A similar fate befel two respectable artizans, who, on returning from their work to St. John's Wood, walked into the Regent's Canal. Fifteen persons are said to have perished in the docks on the north side of the river alone. The losses sustained by the interruption of all traffic were immense. A phenomenon like this, enveloping a huge metropolis in obscurity, is, indeed, a grievous calamity, more full of anxiety and care, entailing more disasters, and causing a greater loss of life, than the most violent thunderstorm. The fog, laden with the smoke of half a million of chimneys, and the countless effluvia of a town embracing a population of more than three millions, had a very curious and terrible effect upon the horned cattle at the Islington show, which, accustomed to a purer air, were unable to breathe in the dense and polluted atmosphere, and exhibited symptoms as if they had been inhaling a noxious gas. Some died, and many others had to be slaughtered, not, as the Irishman said, to save their lives, but for the value of the meat. Curiously enough, the sheep and pigs were but little affected, although the former, no doubt, felt less comfortable than if they had been roaming on the Downs or the Grampian Hills.

Even in times long past, when London was still a comparatively small town, its fogs were already very intense. 'There happened,' says John Evelyn, 'this weeke so thicke a mist and fog, that people lost their waye in the streetes, it being so intense, that no light of candles or torches yielded any or but very little direction. It began about four in the afternoon, and was quite gone by eight, without any winde to disperse it.'

Fogs are very frequent over seas intersected by oceanic currents, whose temperature greatly differs from that of the atmosphere. Thus, the warm waters of the Gulf Stream give rise to dense mists on their progress to the northern latitude, particularly over the banks of Newfoundland. During the fishing season, the fog is generally so heavy in this gloomy region that one ship does not see the other, although both may be so near that the crews distinctly hear each others' voices. Frequently, one is hardly able to see to the distance of a few feet, and the large drops of the condensed mist fall like rain from the yards. During calm weather, the aspect of the sea is so dismal that it requires all the buoyant spirits of a seaman to resist its depressing influence. For days the calm remains unbroken, and no sound is heard but that of a fish darting out of the water, or the screech of a sea bird flitting over the sea. When a storm breaks this awful silence of Nature, the fishing ships, hidden in mists, run the greatest danger of striking against each other, although signal lanterns and alarm trumpets are used to give warning.

For the same reason, the Behring's Sea, where, during the summer, nearly every wind is warmer than the cold waters over which it blows, is almost constantly obscured by mists. Fogs are so frequent about the island of St. Lawrence (65° N. lat.), that navigators have often passed close by without seeing it. At Unalaschka and the other islands of the Aleutic chain, where the warm Japanese ocean current meets the cold winds blowing from the Behring's Sea, fogs are perpetual from April to the middle of July. From this time till the end of September the weather improves, as then the southerly winds drive the fogs more to the north, and enable the sun to shine during a few serene days upon the bleak shores of Unalaschka. But soon the polar air-streams regain the supremacy, and a dismal veil once more shrouds the melancholy island.

The ice-fields of the Arctic Seas are great promoters of mists and fogs, in consequence of their refrigerating influence on the circumambient atmosphere. Every four or five years a large number of icebergs floating from Greenland are stranded on the coasts of Iceland. The inhabitants are then aware that their crops of hay will fail, in consequence of the fogs, which are generated almost incessantly; and the dearth of food is not confined to the land, for the temperature of the water is so changed that the fish entirely desert the coast. Sir C. Lyell[1] remarks, that if the icebergs from the north polar regions floated as far south as those of the Antarctic Seas to the north, they might reach Cape St. Vincent, and then being drawn by the current that always sets in from the Atlantic through the Straits of Gibraltar, be drifted into the Mediterranean, so that the serene sky of that delightful region might soon be deformed by clouds and mists.

Among the foggy regions the coasts of Peru deserve to be mentioned. Here rain is unknown; but in May, which, in these southern latitudes, corresponds to our October, a thin, misty veil spreads over the land, after a summer of intolerable heat, and, increasing in density during the following months, only begins to diminish in October. At the beginning and the end of this damp season, the mist generally ascends between nine and ten in the morning, and falls again at about three in the afternoon; but in August and September, when it is most dense, it rests for weeks immovably over the earth, and then descends in a fine, penetrating drizzle, which is called 'garua' by the inhabitants.

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[1] 'Principles of Geology,' vol. i. p. 244, tenth edition.

The mist seldom ascends to a vertical height of more than 1,200 feet, where it is replaced by violent showers of rain, and, remarkably enough, the limits between both can be determined with the greatest precision, as there are plantations, one half of whose surface is invariably moistened by drizzling mist, and the other by rain.

Though the London fogs enjoy an unenviable celebrity, the number of foggy days in Great Britain is not greater than that which generally occurs throughout northern and central Europe. According to a table given in the 'Meteorology' of Kämtz, the average number of foggy days in London amounts to 33·8; in Stuttgart, to 38·8; in Munich, to 47·1; in Hamburg, to 52·3; in Tegernsee, in the Bavarian Alps, to 134·6; and on the St. Gotthardt, to no less than 277·5; so that on this celebrated pass mists reign during the greater part of the year.

Indeed, fogs are far more frequent in the Alps than in England, and while in our country they chiefly occur in the winter months, they are here more equally distributed over the various seasons, or even predominate in summer, a circumstance which not only deprives the tourist of many a glorious prospect, but may even endanger his life as he wanders among the solitary mountains.

Though mists, even when unattended with danger, are generally unpleasant enough to justify Crashaw's apostrophe—

> Fly, fly, profane fogs! fly hence far away,
> Taint not the pure springs of the springing day
> With your dull influence; it is for you
> To sit and scoule upon night's heavy brow—

they are often not only useful, but have their own picturesque beauties. By preventing nocturnal radiation into space, they preserve many a tender plant from being nipped by the frosts of early spring; and a prospect veiled by a thin fog has its peculiar charms, as it opens a wide field to the imagination, and allows our fancy to picture all sorts of interesting scenes beyond the actual reach of vision. Some of Turner's best paintings represent misty seas with distant masts and sails dimly looming through the vapours, for the great artist well knew that objects seen through an indistinct haze are often more picturesque than when exposed to the full glare of daylight.

When a fog gradually dissolves, and the landscape widens as its veil is withdrawing, and a new world emerges, as it were, out of darkness, the effect is very pleasing. On misty mornings, when the fog was dense below, I have often been delighted while standing above it, on the terrace of the Castle of Heidelberg, to see the curling mists float down the valley of the Neckar, like a fantastic host of huge phantom warriors, their crests gleaming in the early sunshine.

In the Alps it is a grand sight to see the white mists boiling up out of the ravines,

> Like foam from the roused ocean of deep hell.—*Manfred.*

while all above is clothed in light; and nothing can be more magnificent than to look down from the Righi on a silvery sea of mists, breaking in ever-varying waves against the huge mountains that rise above it like islands.

Besides the damp fogs resulting from the condensation of aqueous vapour, there are similar phenomena of a dry nature, which, proceeding from very different causes, have nothing in common with the former but the misty dimness they impart to the atmosphere. One of the most remarkable of these dry fogs is that which is known in Germany under the name of the *Höhrauch.* When this disagreeable phenomenon makes its appearance, the sky assumes a grey tinge, which, at a certain height above the horizon, passes into a brownish haze. Distant hills seem covered with a bluish veil; the sun loses his lustre even at noon, and assumes a blood-red tinge on verging towards the horizon. A peculiar smell of smoke makes the Höhrauch as unpleasant to the olfactory organs as the dulness it imparts to the atmosphere is to the eye. Far-fetched explanations have been formerly given of this dry fog, but it is now well known that it is not due to mysterious electrical influences, but solely to the peat-burnings which annually take place on a grand scale in the heath districts of North Germany. The inhabitants vainly seek to obtain a scanty harvest from the sterile soil by hoeing it in autumn and setting fire in spring to the dried clods. While this burning process is going on, they prevent as much as possible the eruption of flames by stirring the clods, and increase, at the same time, the production of smoke, which rises in enormous quantities and spreads itself in the air. Every year about 60,000 acres are thus set fire to, and the quantity of vegetable matter burnt is estimated at 2,000 millions of pounds. This may serve to explain the wide extension of the Höhrauch, which spoils the enjoyment of many a fine summer day in Northern Germany, or even to a much greater distance. In Westphalia the smoke is often so thick that one is hardly able to see the sun; and as, on account of its density, it seldom rises to a height of 1,000 or 1,500 feet, it is sometimes carried by the wind as far as Berlin, Bâle, and Paris, where it veils the hills with a light blue haze. To settle the question of its origin, Dr. Finke followed it to its source, and found that it spread to a distance of 150 miles without losing much of its original density. When a continued rain falls throughout the country, while the peat burnings take place, it absorbs the smoke, while a dry state of the atmosphere favours its wide extension.

In large towns, where immense quantities of coal are consumed, the air is almost always tainted with a kind of Höhrauch. From an enormous distance the thick, murky cloud settling over London indicates its site; and even on the finest days, a yellowish haze dims the perspective of its interminable thoroughfares.

A phenomenon similar to the Höhrauch is also observed in North America, from the State of Missouri to New England and Upper Canada. About the end of October and in November, the enjoyment of that beautiful part of the year called the Indian summer is more or less disturbed by a hazy condition of the atmosphere. Beyond all doubt this phenomenon arises from the custom of the Indians and hunters to set fire to the woods, prairies, and moors after most plants have been dried up by the summer; for, since the Indians, giving way to the progress of the pale faces, have withdrawn into wildernesses more and more remote, this dry fog has perceptibly decreased both in extent and duration.

Dr. Livingstone likewise mentions a murky state of the atmosphere, which frequently dims the lovely scenery of the

Barotse Valley. This peculiar tinge, which is observed every winter at Kolobeng, is attributed to the burning of grass; but, as it is not seen in other places, where the firing of the dry herbage is much greater, some other explanation must be sought. He sometimes imagined that the lowering of the temperature in the winter rendered the vapour in the upper current of air visible, and imparted this hazy dimness to the atmosphere.

The Spanish *Caliña* is in appearance very like the Höhrauch. Willkom observed this dry fog in the parched plains of the Guadalquivir, where, during the whole summer, it dims the distant prospect. At first a narrow stripe of mist of a bluish grey tinge forms on the skirts of the horizon, and, growing in the same proportion as the heat increases, covers towards the middle of August about one-fourth of the sky. As soon as the heat begins to decrease in September, the fog also diminishes, and finally disappears after the first equinoctial gales. When, in summer, a thunderstorm cools and purifies the atmosphere, it also sometimes decreases, but after a few days regains its former extension. As the Caliña is entirely without the smell of burning peculiar to the Höhrauch, it has evidently another origin. As its name (derived from the Latin *calor*) denotes, the Spaniards attribute it to heat, which causes the particles of various substances to ascend and to float in the air as dust.

Among the causes which sometimes produce an extensive darkening of the air, by filling it with inorganic particles, we have also to mention volcanic eruptions.

The finest ashes, reduced to an impalpable grey powder, especially towards the close of a paroxysmal explosion, are borne by the winds that may prevail at the time to distances which may well be called prodigious. Thus, in 1812, the ash-dust thrown up by a volcanic eruption on the island of St. Vincent plunged Barbadoes into darkness; and, in 1794, all Calabria was enveloped in clouds of smoke, which proceeded from an eruption of Mount Etna.

The glowing lava streams, which, as they flow along, scorch all the plants they meet with, likewise give rise to a vast quantity of smoke.

According to Chladni, to whom science is indebted for many acute observations, dry fogs have also a cosmic or extra telluric origin. He attributes some highly remarkable and extraordinary cases of dry fog to the intrusion into our atmosphere of extremely attenuated matter, like that which forms the shooting stars and meteoric stones; and though this theory seems bold, it may in some cases be correct. For if large and visible planetary masses are frequently showered down upon the earth from the distant realms of space, there is good reason to believe that planetary matter in a state of nebulous division may also sometimes be mingled with the air. The dry fog which, in the year 526 of our Lord, the sixth of the reign of Justinian, covered the East Roman Empire with a reddish haze, may possibly have been of this nature; as well as the remarkable phenomenon which, in 1783, obscured the air over a considerable part of the globe.

It appeared on May 24 at Copenhagen, on June 6 at La Rochelle, on the 18th at Göttingen. It spread over Syria and the Altai Mountains; it was observed over a great part of North America; and Saussure, Lamanon, and Senebier, met with it on the highest summits of the Alps. It showed no trace of humidity, was not affected by rain or wind, and it extended alike over countries of 'distempered climate' like our own, and others where the skies are usually bright. It veiled the atmosphere with a pale blue haze, and was sometimes so dense that at a distance of a thousand paces the houses and trees could not be seen; the sun only became visible when it stood 12° above the horizon, and on rising and setting it had a blood red colour, without any brightness. The fog had a strong disagreeable odour, and in some places popular rumour, ever prone to exaggeration, affirmed that a viscid acrid substance was deposited by it. Its duration was various in different places; for while it was seen but one month in Paris, Stockholm, and Geneva, it lasted three months in Rome, and four in Mannheim and Copenhagen. The greatest alarm prevailed; men's hearts failed them for fear. Says Cowper, alluding to this fog:—

> Is it a time to wrangle, when the props
> And pillars of our planet seem to fail;
> And Nature, with a dim and sickly eye,
> To wait the close of all?—*The Task*, Book II.

More terrible visitations were expected. Public prayers were earnestly made to avert the apparently impending doom of all Europe, and the popular mind was as agitated as during periods of war or revolution. Awful thunderstorms visited the Continent, desolated France, and destroyed a large number of human beings and cattle in England. It was a time of terror, of tumult, and of universal excitement. As long as this portentous haze lasted, a severe epidemic catarrh, arising probably from the irritating effects of the fog on the respiratory organs, affected men and animals.

But the most remarkable phenomenon which attended this fog, as well as a similar one which, in 1831, spread over a great part of the northern hemisphere, was its peculiar phosphoric gleam by which it was possible to read the smallest print at midnight in the month of August, so that as long as the mist lasted in any place, no complete darkness took place during the night. At the date of the dry fog of 1831, the sun's disk was also seen of a blue or green colour in the south of Europe and in America. Sir David Brewster communicated at Glasgow an account of this phenomenon, observed by Dr. Harvey at Bermuda, who, however, does not appear to have remarked the blueness of the sun, but only that of objects illumined by it. 'I rose early,' says the doctor, 'for the purpose of writing, and soon discovered the light was so dim that I could not proceed. I removed to another room, and finding my situation not improved, I said, in the presence of one of my family, I apprehended a sudden failure of sight. I was then asked if I had not observed a very peculiar appearance of the sun's rays the day before. I had not, but had perceived the floor of the room to look *blue*, especially where the sun shone on it; indeed, every object in the room appeared of a sickly blue colour. The next day, the 12th, a mail boat was put under weigh with a party on board. The day was so mild and tranquil we could only reach a few miles; the sails, which were new and pure white, nevertheless appeared to be stained of a bluish colour, and the sea was of a dingy yellow.'

Such extraordinary atmospherical phenomena are well calculated to awaken serious thoughts. They shake, as it were, the firm foundation of our belief in the permanent stability of the course of Nature, and show us at least the possibility of unexpected disasters befalling our race from the distant regions of space. We have merely to suppose a cloud of nebulous matter, somewhat more dense and more pernicious than those which have at times already visited the earth, obscuring the sun for several months, so as to prevent all vegetation, and carrying the germs of mortal disease in its misty shroud; and what then becomes of proud man, who fancies himself the centre of creation, and so soon forgets the lessons of humility which his weakness should teach him?

CHAPTER X.

DEW.

Erroneous Opinions of the Ancients on the Origin of Dew—The Alchemists and Rosicrucians—The Cosmetic Properties of Dew—The Phenomena of Dew—Circumstances which Favour and Hinder its Formation—Dr. Wells' Theory of Dew—Moon Blindness—Nipping of Tender Plants by Frost—Rime and Hoar-frost—Important Duties of Dew in the Economy of Vegetable Life—Injurious Properties Falsely Ascribed to it.

OF all the forms in which the condensed aqueous vapour of the atmosphere descends upon the earth, there is none so constantly beneficial to the husbandman as dew. The rain he so anxiously longs for after a period of drought becomes as great a source of care when it continues beyond a certain time, or is precipitated in cataracts from the opened sluices of the sky; but dew, which so gently and refreshingly moistens the thirsty fields, and never condenses into superabundant showers or disastrous floods, is always welcomed as a friend.

The lover of Nature also delights in its crystal drops, glittering like diamonds on the grass, or sparkling in all the colours of the rainbow among the foliage; and the poet often introduces it in his pictures of early morn—

When we see
The fresh dropp'd stores of rosy dew,
Transparent beauties of the dawn,
Spread o'er the grass their cobweb lawn,
And hang moist pearls on every tree;

or uses it as a charming simile in his descriptions of female beauty; as, for instance, Scott, in the Minstrel's Song to the Maid of Lorn:—

O wake, while Dawn with dewy shine,
Wakes Nature's charms to vie with thine!

She bids the mottled thrush rejoice
To mate thy melody of voice;
The dew that on the violet lies,
Mocks the dark lustre of thine eyes.

Thus dew has always been a source of pleasure to man, but it is only in our times that the cause of its formation has been satisfactorily explained. The ancients, who had very erroneous notions of the physical laws which govern the atmospherical phenomena, supposed it to be dropped from the stars; and the alchemists of the middle ages held it in high estimation, as one of their most powerful menstruums. Wonderful properties were more especially ascribed to May dew, by whose intervention and assistance they vainly sought for the philospher's stone, which was supposed to confer immortality and riches on its fortunate discoverer.

The Rosicrucians, a peculiar sect of alchemistical fanatics or quacks, have even derived their name from the Latin *ros*, which signifies dew, a proof of the high importance attached to it in their delusive art.

When men, often of no mean intellect, are thus known to have wasted their time and energies in the pursuit of the most extravagant chimeras, we cannot be surprised that the ladies of antiquity attributed to dew the magical power of preserving their beauty, and collected it, as we are told, by exposing fleeces to the night air, and wringing them out in the morning. Even now there are many fair believers in its virtues; and indeed this confidence is in some measure not misplaced, for in a figurative sense there is no better cosmetic for young ladies than to bathe their faces in dew, provided they rise early and collect it themselves in the fresh morning air.

As late as the beginning of the present century, natural philosophers were still disputing whether dew was formed from vapours ascending from the earth during the night time, or from the descent of such as had been already raised through the day, both parties endeavouring to justify their opinions by fanciful theories. At length, Dr. Wells, a London physician, struck out the true path of careful observation, and fully proved that dew is occasioned by the chilling which bodies near the surface of the earth experience in consequence of nocturial radiation. Their temperature having then sunk several degrees below that of the circumambient air, it frequently happens that this temperature is below that at which the atmosphere is saturated. The layer of air which is immediately in contact with the chilled bodies, and which virtually has the same temperature, then deposits a portion of the vapour which it contains; in the same manner as a bottle of cold water, when brought into a warm room, becomes covered with moisture, in consequence of the condensation of aqueous vapour upon its surface.

All causes which promote the cooling of bodies increase the quantity of dew. These causes are the emissive power of bodies, the state of the sky, and the agitation of the air. Bodies which have a great radiating power more readily become cool, and therefore ought to condense more vapour. In fact, there is generally no deposit of dew on metals, whose radiating power is very small, especially when they are polished; while the ground, sand, painted wood, and particularly plants, which have a considerable radiating power, are abundantly covered with dew. For this reason grass often becomes moist soon after sunset, while adjacent gravel walks exhibit as yet no signs of humidity. Plants with a hairy foliage are particularly good condensators of dew, since, from exposing a greater surface in the same space to the refrigerating causes, they lose heat more rapidly than those with smooth leaves.

The state of the sky also exercises a great influence on the formation of dew. If the sky is cloudless, the planetary spaces send to the earth an inappreciable quantity of heat while the earth radiates very considerably, and therefore becoming very much chilled, there is an abundant deposit of dew. We can thus understand why dew is more plentiful in autumn and spring than at any other season, as then very cold nights follow upon warm days, during which a copious evaporation took place; and why it is most abundant in the torrid zone, as in those regions the sultry air generally contains a greater quantity of aqueous vapour than in more temperate climates, and the comparatively cold nights are almost constantly serene and calm. Thus the tropical sun rises in its strength upon a landscape which the gentle hand of night has cooled with refreshing dew. Though no rain-carrying cloud may cross the blue air during the day to shed its refreshing waters upon the parched earth, the clear and brilliant evenings afford a grateful and efficient compensation, and the thirsty vegetation is enabled without injury to endure the rays of the burning luminary all the day long.

While a cloudless sky favours the radiation of terrestrial heat, clouds, on the contrary, having a far higher temperature than that of the planetary spaces, radiate in turn towards the earth; and as then the bodies on the surface of the earth only experience a feeble chilling, no deposit of dew takes place.

Wind also influences the quantity of vapour deposited. If it is feeble, it increases it, inasmuch as it renews the air; if it is strong, it diminishes it, as then the air in contact with the ground is constantly removed before it has time to cool so far as to compel it to part with its moisture. Finally, dew is more abundant according as the air is more charged with aqueous vapour, for then it is nearer to its point of saturation.

We consequently find very copious deposits of dew in well-watered countries, in the vicinity of lakes and swamps, where the air is constantly moist. For this reason its formation in the coast lands of the equinoctial regions is frequently so abundant that the water drips from the trees as if it rained. In the interior of large arid continents, as, for instance, in the African Desert, in Nubia, and part of Brazil, where the air contains but little aqueous vapour, dew is a rare phenomenon.

In shady places dew sometimes begins to form early in the afternoon, when the sultry atmosphere is so laden with aqueous vapour that a slight decrease of temperature suffices to cause its partial precipitation on radiating surfaces. Then the grass not seldom gets damp a few hours before sunset. Generally, dew is most profuse in the clear morning hours which have been preceded by a clouded night. Plants standing under trees condense less dew than those which grow in the open air, as the leafy canopy acts like a cloud by preventing radiation. In small gardens surrounded by high walls, there is little or no dew, as the walls radiate the heat they have absorbed during the day, and restore to the ground the loss of warmth it sustains by simultaneous radiation into planetary space. Thus, all the various phenomena of dew are satisfactorily accounted for by the ingenious theory of Dr. Wells, who, though only a simple practitioner of the healing art, and previously unknown to fame, discovered, by dint of patient observation, some of the most interesting laws of atmospherical physics, which so many learned academies had vainly endeavoured to explain.

The experiments on which he founded his theory were made in a garden in Surrey, at a distance of three miles from Blackfriars Bridge, and are cited by Professor Tyndall as models of ingenious investigation. To collect this dew he used little bundles of wool, weighing ten grains each when dry, and having exposed them during a clear night, the increase of their weight indicated the quantity of dew deposited on them. He soon found that whatever intercepted the view of the sky from his piece of wool, diminished or prevented also the deposition of dew. He raised a board on four props; *on* the board he laid one of his wool parcels, and another *under* it; during a clear calm night the former gained fourteen grains in weight and the latter only four. He bent a sheet of pasteboard like the roof of a house, and placed under its shade a bundle of wool on the grass; by a single night's exposure, the wool gained two grains in weight, while a similar piece of wool freely exposed on the grass collected sixteen grains of moisture.

Dr. Wells next exposed thermometers to the night air as he had done his wool bundles, and found that the temperature sank lowest where the dew fell most copiously. On the propped board he found the temperature 9° F. lower than under it, and 10° less on the open grass than beneath the pasteboard roof. He also found that on a clear night, a thermometer suspended in free air, four feet high above the grass, was sometimes 14° warmer than a similar thermometer laid upon a grass plot, and that a piece of cotton placed beside the former gained only eleven grains in weight, while a similar bit beside the latter gained twenty grains. The lowering of the temperature and the deposition of the dew were thus found to go hand in hand. Clouds crossing the zenith at once raised the temperature of the thermometer, which fell again as soon as the sky was clear.

Another series of experiments showed that the quantity of dew deposited on bodies under similar circumstances depends on their radiating power. On one occasion he placed a plate of metal upon grass, and upon the plate he laid a glass thermometer; the thermometer after some time exhibited dew, while the plate was dry. A second thermometer with a gilt ball was now placed beside the first; the naked glass thermometer—a good radiator—remained 9° F. colder than its companion.

Having thus accumulated facts which unquestionably proved dew to be an effect of chilling by radiation, Dr. Wells gave to the world his admirable theory of dew. 'His essay,' says Professor Tyndall, 'is a model of wise enquiry and of lucid exposition. He made no haste, but he took no rest till he had mastered *his* subject, looking stedfastly into it until it became transparent to his gaze. Thus he solved his problem, and stated its solution in a fashion which renders his work imperishable.'

Dr. Wells applied his principles to the explanation of many curious effects, and to the correction of many popular errors. He pointed out that moon-blindness is owing to the chill produced by radiation into clear space, the shining of the moon being merely an accompaniment to the clearness of the atmosphere, and that the putrefying influence ascribed to the moonbeams is really due to the deposition of moisture on the exposed animal substances. The nipping of tender plants by frost, even when the air of the garden is some degrees above the freezing point of water, is also an effect of the chill produced by radiation. That a slight screen is sufficient to protect them from injury is a fact that was well known to practical gardeners long before its cause was ascertained. 'I had often,' says Dr. Wells, 'in the pride of half-knowledge, smiled at the means frequently employed by gardeners to protect tender plants from cold, as it appeared to me impossible that a thin mat, or any such flimsy substance, could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned that bodies on the surface of the earth became, during a still and serené night, colder than the atmosphere by radiating their heat to the heavens, I perceived immediately a just reason for the practice which I had before deemed useless.'

Dew is the purest form in which water is found. Rainwater is more or less charged with impurities, and even the distilled water of the chemist contains them in a very minute degree; but dew may be considered as perfectly pure water when it forms on a clean surface.

Rime and hoar frost are nothing more than dew which has been deposited on bodies cooled below zero, and has therefore become frozen. The flocculent form presented by the small crystals of which rime is formed, shows that the vapours solidify directly, without passing through the liquid state. Hoar-frost, like dew, is formed on bodies which radiate most, such as the stalks and leaves of vegetables, and is chiefly deposited on the parts turned towards the sky. The sudden irruption of a warm, moist wind after a long, protracted, heavy frost, favours its formation. Then beautifully shaped needles of ice attach themselves to all uneven radiating surfaces, particularly to the trees, whose smallest branchlets appear incrusted with silvery crystals. A forest of firs thus prodigally decorated with snow-white fringes and tufts affords a truly enchanting spectacle, particularly when the sun shines upon it, and a dark-blue sky forms the background of the charming winter landscape. The most magnificent stalactital grotto which required centuries for the formation of its fairy ornaments, is not more beautiful than this growth of a single night.

In Newfoundland, the sudden irruption of a warm south wind, laden with the exhalations of the Gulf Stream, soon covers the chilled woods with mighty ice-crusts, and the silver dew, as the phenomenon is called, transforms every tree into a candelabrum of the purest crystal.

Besides affording the plants a grateful and efficient compensation for the want of rain, dew fulfils another important duty in the economy of vegetable life. At sunrise, the roots of the herbage plunged in the cooled soil, are not yet sufficiently active in absorbing moisture, and the leaves, suddenly exposed to the rays of the sun, would wither, their transpiration being stronger than the supply of water derived through the roots, if the dew by its evaporation did not protect them against the sudden effects of heat, and give the roots time to regain their functional strength.

The injurious properties that have been attributed to dew are purely imaginary. It is beyond all doubt quite guiltless of the colds and rheumatisms which are apt to befal careless persons, who, after a warm day and but thinly clad, continue to sit in the open air while the chilled plants are covering with dew. A no less erroneous opinion ascribes the appearance of mildew to a sweetish glutinous substance supposed to descend with the dew from the skies, and to attract the incredible multitude of plant-lice which often infest our gardens.

CHAPTER XI.

CLOUDS.

Aristophanes and Shelley—The Picturesque Beauty of Clouds—Wordsworth-Classification of Clouds by Luke Howard—The Cirrus or Curl-cloud—The Cumulus or Heaped-cloud—The Stratus Cloud—The Nimbus or Rain-cloud—Intermediate Forms—The Mackerel Sky—The Formation of Clouds—Hutton's Theory—The Spreading of the Tablecloth on Table Mountain—The Play of Clouds in the Alps Described by Goethe—The Clouds in the Highlands of Quito—Clouds Formed by Active Volcanos—Observations of Dr. Wagner on the Clouds Forming over Cotopaxi—How do Clouds remain Suspended in the Air?—Their Height—Balloon Observations—Rain-clouds Four Miles High.

'LUMINOUS, never resting, inexhaustible, we ascend from the unruly bosom of Father Ocean and fly upwards to the forest-crowned summits of the mountains. We look down upon pinnacles shining from afar, on cornfields, on the holy nourishing earth, and the god-like rivers as they flow along to join the floods of the heaving, hoarse-resounding sea. We shake from our immortal bodies their dewy robes, and gaze over the wide earth with a lustrous eye.'

Such is the lofty strain of the Chorus of the 'Clouds' in the famous play of Aristophanes, which strove to make Socrates an object of ridicule; and still more beautiful is the bold imagery of Shelley's 'Cloud,' singing the evolutions and transformations of her aerial career.

I bring fresh showers for the thirsty flowers,
  From the sea and the streams;
I bear light shade for the leaves when laid
  In their noonday dreams.
From my wings are shaken the dews that waken
  The sweet birds every one,
When rocked to rest on their mother's breast
  As she dances about the sun.

I wield the flail of the lashing hail,
  And whiten the green plains under;
And then again I dissolve it in rain,
  And laugh as I pass in thunder.

I am the daughter of earth and water,
  And the nursling of the sky;
I pass through the pores of the ocean and shores—
  I change but I cannot die.
For after the rain when with never a stain
  The pavilion of heaven is bare,
And the winds and sunbeams with their convex gleams
  Build up the blue dome of air.
I silently laugh at my own cenotaph,
  And out of the caverns of rain,
Like a child from the womb, like a ghost from the tomb,
  I arise and unbuild it again.

The phenomena thus eloquently described by two great poets are indeed worthy of admiration; for the clouds, these fleeting daughters of the ever changeful atmosphere, which, when they envelope us with a thick veil, are nothing but a grey and formless mist, become objects of rare beauty when sailing through the luminous atmosphere, in picturesque forms, and adorned with all the enchantments of colour. Unpleasant when near, they become charming at a distance, like so many other things which we long for when far from our reach, and find to be but little worth when we grasp them.

Aloft in the sky, or rising above the horizon, the clouds frequently gladden our eye, which fancies it sees vast piles of snow-clad mountains rise over the level plain, or follows the aerial wanderings of a strange procession of monstrous shapes, and at every metamorphosis of their tints and outlines assists, as it were, at the birth of a new fantastic world.

Lo! in the burning west, the craggy nape
Of a proud Ararat! and thereupon
The Ark, her melancholy voyage done;
Yon rampant cloud mimics a lion's shape;
There combats a huge crocodile—agape,
A golden spear to swallow! and that brown
And mossy grove, so near yon blazing town,
Stirs and recedes—destruction to escape.

> Yet all is harmless—as the Elysian shades
> Where spirits dwell in undisturbed repose—
> Silently disappears or quickly fades;
> Meek Nature's evening comment on the shows
> That for oblivion take their daily birth
> From all the fuming vanities of Earth.—WORDSWORTH.

Thus, at all times, the capricious imagery of the clouds has been a fruitful theme both for the poet and the moralist; but the idea of analysing the various forms of clouds with respect to their meteorological significance, and of subjecting them, as it were, to the rule of fixed laws, is of modern date. The honour of having been the first pioneer in this branch of science belongs to Luke Howard, a member of the Society of Friends, who, struck by the remarkable dry fog of 1783, turned his attention at an early age to the observation of atmospherical phenomena. Later in life, being employed in a chemical manufactory, and obliged to pay frequent visits to a distant workshop, he had many opportunities of studying the clouds, and finally submitted the result of his observations to the Royal Society.

According to their appearance, the clouds have been divided by Howard[1] into four principal kinds: the *nimbus*, the *stratus*, the *cumulus*, and the *cirrus*, which are respectively designated in the following woodcut by one, two, three, or four birds on the wing.

The cirrus or curl-cloud has its seat in the higher regions of the atmosphere, where it is either seen scattered in small, fleecy masses, or floating in long, narrow stripes, an appearance well described by the popular name of *mare's tails*. White by day, the cirri often glow after sunset with the liveliest golden or roseate hues; for, like the snowy Alpine peaks, they are still bathed in light while darkness is covering the lower atmosphere. When, after a long continuance of fine weather, a change is about to take place, these light clouds are often its first signs, as they indicate the approach of a warmer and humid air current. Rain is soon to be expected when their borders become indistinct—a sign that the condensation of the vapours is increasing, and when, at the same time, the blue colour of the sky begins to fade. On the other hand, dry weather will probably continue for a few days longer, when the borders of the cirrus are distinctly marked on a cerulean background.

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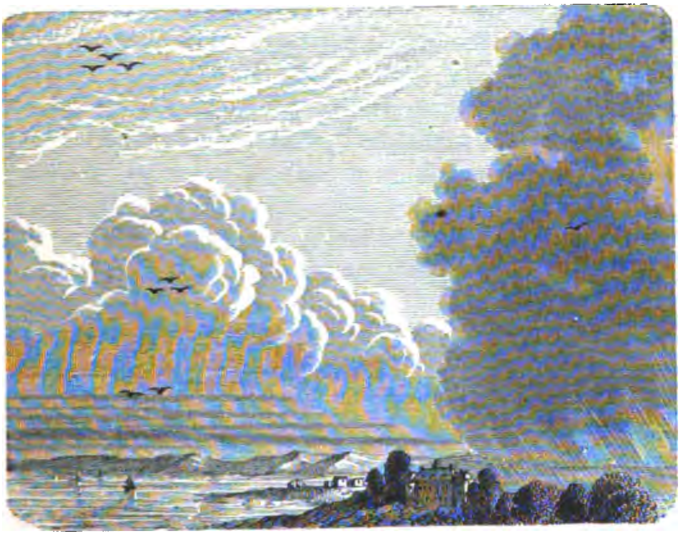
[1] Goethe, who took a lively interest in all meteorological phenomena, had a great esteem for Howard, and says of his observations that they plainly show 'how, without being sought for, the finest results often fall to the share of a contemplative mind at peace with itself and the world.'

From the low temperature of the high spaces which they occupy, it is more than probable that cirrus-clouds consist of frozen particles; and hence it is that haloes, coronae, and other optical appearances, produced by refraction and reflexion from ice crystals, appear almost always in these clouds and their derivatives.



CLOUDS.

The cumuli, or heaped clouds, are rounded spherical forms, piled one on the other, and either light coloured throughout or with white borders. They often form picturesque groups on the horizon, and, when shone upon by the sun, resemble distant snow mountains. They are more frequent in summer than in winter; and, after being formed in the morning, they generally disappear towards evening. 'In their bosom,' says Goethe, 'the conflict between fair and foul weather is preparing, as it is still undecided whether they are to rise and dissolve in the air or to descend in showers.

As long as their borders are sharply defined, and have a white colour, a continuance of good weather may be expected.'

Stratus-clouds consist of very large and continuous horizontal sheets, which chiefly form at sunset and disappear at sunrise. They are frequent in autumn and unusual in spring time, and are lower than the preceding.

The nimbus or rain-clouds, which are sometimes classed as one of the fundamental varieties, are properly a combination of the three preceding heads. They affect no particular shape, and are solely distinguished by a uniform grey tint, and by fringed edges.

The fundamental forms pass into one another in the most varied manner, so that it is often very difficult to tell from the appearance of a cloud which type it most resembles. Howard has classed these intermediate or transitional forms as Cirro-cumulus, Cirro-stratus, and Cumulo-stratus. The Cirro-cumulus is commonly called a 'mackerel sky.' It consists of small, roundish masses, disposed with more or less irregularity and connexion. It is frequent in summer, and attendant on warm and dry weather. Cirro-stratus appears to result from the subsidence of the stripes of cirrus to a horizontal position, while, at the same time, they are joining laterally. The form and relative position, when seen in the distance, frequently give the idea of shoals of fish. The tendency of cumulo-stratus is to spread, settle down into the nimbus, and finally fall as rain.

Clouds differ from fogs only in occupying the higher regions of the atmosphere. They always result from the condensation of the aqueous vapour floating in the atmosphere. Many causes may concur in their formation. The vapours which, owing to solar radiation, are constantly disengaged from the land and from the waters, ascend in the atmosphere from their elastic force and lower density. As they rise, they meet with continually colder and colder layers of air, until they sink to the point of saturation, and then, condensing into infinitely small droplets, give rise to clouds. The expansion which takes place on their ascent in consequence of the gradually feebler pressure which they undergo —and the cold thus produced—must necessarily be a frequent source of condensation and cloud formation.

Besides the chill which accompanies the rarefaction of ascending air, radiation into space must also be taken into account as a cause of condensation, for the aqueous vapour which intercepts the passage of heat from the earth into space radiates it as copiously as it absorbs it. Imagine a column of saturated air ascending on a warm day, and for a time the vapour entangled in this air will be surrounded by air almost fully saturated. The ascending vapour radiates, but it radiates into the surrounding vapour, which, in a great measure, returns the heat thus imparted to it, so that condensation under such circumstances is rendered difficult. But the quantity of aqueous vapour diminishes speedily as we ascend, and finally it finds itself elevated beyond the protecting screen, which, during the first portion of its ascent, was spread above it. It is now in the presence of pure space, and into space it pours its heat without hindrance or requital. 'Cumulus clouds,' says Professor Tyndall, 'are the heads of columns of vapour which rise from the earth's surface and are precipitated as soon as they reach a certain elevation. Thus, the visible cloud forms the capital of an invisible column of saturated air. Certainly the top of such a column, raised above the lower vapour screen which clasps the earth, and offering itself to space, must be chilled by radiation; in this action alone we have to some extent a physical cause for the generation of clouds.'

The condensation of vapour brought about by the cooling which a hot, moist current of air undergoes when mixing with a colder current is thus explained by Hutton. The tension of aqueous vapour, and consequently the quantity present in a given space, when saturated, diminishes according to a geometric progression, while the temperature falls in arithmetical progression, and therefore the elasticity of the vapour present at any time is reduced by a fall of temperature more rapidly than in direct proportion to the fall. Hence, if a current of warm air saturated with aqueous vapour meet a current of cold air, also saturated, the air acquires the mean temperature of the two, but can only retain a portion of the vapour in the invisible condition, and a cloud or mist is formed.

The various condition of the earth's surface frequently gives rise to the local formation of clouds. As land and water do not impart the same quantity of heat to the atmosphere, and the different kinds of ground are unequally heated by the sun, these variations must necessarily have a considerable influence on the dissolution or condensation of the aqueous vapour contained in the air.

Hence clouds which have been formed over forests and damp fields disappear over arid deserts or heated plains, and the navigator is frequently apprised of the vicinity of an island by the clouds resting over it, although it is still below the horizon.

To a practised eye, the topography of the earth rind mirrors itself in some measure in the flighty creations of the atmosphere; and it is even said of the Indians, whose acute senses far outreach the dull perceptions of civilised man, that wherever the axe of the colonist has not yet wrought a change in the primeval features of the country, they are able to trace the course of the rivers in the skies.

When a warm, moist current of air strikes against a mountain, it is forced upwards along its side, and on attaining a certain height often forms a cloud through the condensation of its aqueous vapours. One of the most interesting phenomena of this kind is the so-called spreading of the table-cloth on the famous Table Mountain at the Cape of Good Hope. The atmosphere above this mountain is generally clear and serene; but in the mild or summer season, which commences in September and continues till March, the south-easterly monsoon, laden with the emanations of the Indian Ocean, sometimes condenses its humidity into a thick, snow-white cloud, which, carried by the winds over the flat, horizontal summit of the mountain, rolls down in stripes on the opposite side, without, however, reaching its foot, as, about midway down, it is re-dissolved in the warmer strata of air. New clouds are in this manner constantly forming on one side and as constantly melting away on the other, and thus the elements continue for some time their antagonistic play.

Similar phenomena are of frequent occurrence on fine, sunny days in the Alps, when clouds are constantly forming and dissolving on the snow-fields and naked pinnacles, according as the mists condense over the cold glaciers or melt away in a warmer current of air. Sometimes, from a distant point of view, a lofty peak may be seen disappearing behind a thick veil of mists, while another is emerging from the dispersing clouds, and now a wide snow-field, which erewhile shone brilliantly in the sun, is obscured by a grey pall, while another begins to gleam forth from its misty shroud. 'The shiftings of the atmosphere,' says Professor Tyndall,[1] describing one of these aerial *dissolving* views, 'were wonderful. The white peaks were draped with opalescent clouds, which never lingered for two consecutive minutes in the same position. Clouds differ widely from each other in point of beauty, but I had hardly seen them more beautiful than they appeared to-day, while the succession of surprises experienced through their changes were such as rarely fall to the lot even of a practised mountaineer. These clouds are for the most part produced by the chilling of the air through its own expansion. When thus chilled, the aqueous vapour diffused through it, which is previously unseen, is precipitated in visible particles. Every particle of the cloud has consumed in its formation a little polyhedron of vapour, and a moment's reflection will make it clear that the size of the cloud-particles must depend, not only on the size of the vapour polyhedron, but on the relation of the density of the vapour to that of its liquid. If the vapour were light and the liquid heavy, other things being equal, the cloud-particle would be *smaller* than if the vapour were heavy and the liquid light. There would evidently be more *shrinkage* in the one case than in the other. Now there are various liquids whose weight is not greater than that of water, while the weight of their vapour, bulk for bulk, is five or six times that of aqueous vapour. When those heavy vapours are precipitated as clouds, which is easily done artificially, their particles are found to be far coarser than those of an aqueous cloud. Indeed, water is without a parallel in this particular. Its vapour is the lightest of all vapours, and to this fact the soft and tender beauty of the clouds of our atmosphere is mainly due.'

The highly interesting spectacle of the formation of clouds in the high regions of the earth could not fail to attract the attention of Goethe. 'I have entered the portal,' says the great poet, who, at the foot of the Gemmi, had been observing the mists ascending from the gorges; 'I have been attending for some time the birth of the clouds, which is inexpressibly beautiful. They rise from the deep chasms up to the highest mountain peaks, and, attracted by these, they seem to condense, and, seized by the cold, to precipitate in the form of snow. Sometimes covering enormous rocks with impenetrable gloom, and then again affording spectral glimpses of them, they impart a kind of melancholy life to these dismal solitudes. In a low country we are accustomed to consider clouds as strangers, as birds of passage, which, born under another sky, pay us short visits on their migration from one land to another; or as a magnificent tapestry, through which the gods hide their splendour from our gaze. But here they envelope us as they are born, and as we follow their transformations we feel as if we had caught a glimpse of the eternal and secret operations of Nature.'

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[1] 'Macmillan's Magazine,' March 1860.

ELECTRIC CLOUD WITH LIGHTNING ON SIDE OF ANDES.

The spectacle of the formation and dissolution of clouds is described as particularly grand in the colossal amphitheatre of snow mountains which bounds on every side the horizon of Riobamba, in the highlands of Quito. A broad cloud-belt condenses about the waist of a huge trachytic cone, and soon lightnings flash forth from its bosom, and hail and rain pour down. High above the storm the dazzling snow-peak detaches itself from the deep blue sky. The atmosphere is beautifully clear, so that in spite of the enormous distance all its outlines are distinctly marked; and yet the brilliant colossus is cinctured with a cloud that seems to emerge from his own bosom. After precipitating its contents the cloud dissolves into a misty veil, but soon condenses anew, and thus appears and disappears again and again.

Active volcanos exhale from the fumaroles of their craters an enormous quantity of steam, which, whirling upwards into the higher regions of the atmosphere, condenses into a heavy cloud. These nebulous masses are very different in form and colour from all other cloud formations, and can be recognised from a vast distance. The Andes, whose volcanic cones generally rise high above the snow-line, afford excellent opportunities for the study of the peculiar nature of volcanic clouds.

'During every great steam explosion of the crater,' says Wagner,[1] 'which Cotopaxi repeats at least five or six times daily, even when he is in his ordinary state of activity, a light, whitish cloud first rises from the mouth of the crater, and is soon after followed by a thick, dark grey or blackish mass of vapours. This darker colour results from the quantity of dust and ashes with which it is mingled. The higher the cloud ascends, and the wider it expands, the lighter its colour becomes. Its broad contours, clearly defined against the dark blue sky, are white, while its body remains dark grey. Each great steam explosion lasts from ten to fifteen minutes, and then suddenly ceases. The cloud, rising higher and higher, at length separates completely from the volcano. If before it resembled a gigantic plume of feathers waving over the silvery helmet of the mountain, it now appears like a canopy suspended over its summit. He who has never witnessed this spectacle can hardly form an idea of its picturesque beauty. For three or four hours after its birth, the volcanic cloud can still be distinguished as such by its density, its remarkable form, and its peculiar colour, until its aqueous particles, spreading further and further, are finally lost in the atmosphere, or mingle with ordinary clouds.'

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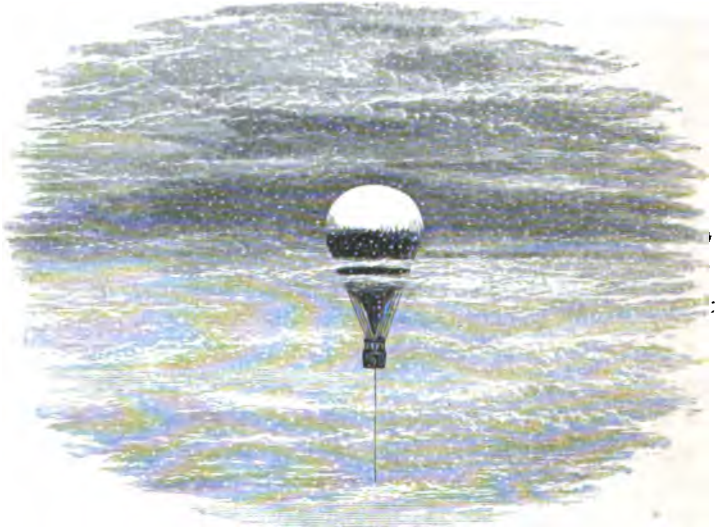
[1] 'Naturwissenschaftliche Reisen im tropischen Amerika,' 1870.

At first sight it seems incomprehensible how clouds can remain floating in the air, as they are composed of water, which, however minutely divided, must still from its greater weight be precipitated upon the ground. In order to explain their suspension in the air, Halley first proposed the hypothesis of vesicular vapours. He supposed that clouds are formed of an infinity of extremely minute vesicles, hollow, like soap bubbles, filled with air which is hotter than the surrounding atmosphere, so that the vesicles float in the air like so many small balloons. This theory has at present many opponents, who assume that clouds and fogs consist of extremely minute droplets of water, which are retained in the atmosphere by the ascensional force of currents of hot air, just as light powders are raised by the wind. Generally, clouds do not appear to descend, but this absence of downward motion is only apparent. In fact, clouds do usually fall slowly, but then the lower part is continually dissipated on coming in contact with the lower and more heated layers; at the same time, the upper part is always increasing from the condensation of new vapours, so that from the joint and contrary action of cold above and heat below, clouds, though their individual vesicles or droplets are constantly changing, and, in fact, perpetually falling, often appear to remain stationary at the same altitude.

The height of clouds varies considerably; in the mean, it is from 1,300 to 1,500 yards in winter, and from 3,300 to 4,400 yards in summer. It is generally assumed that the nimbus or rain-cloud occupies the lowest level, and that on rising to the higher regions the clouds gradually diminish in density, and finally disappear. Kämtz calculated the height of sharply-defined clouds at from 3,000 to 10,000 feet, and that of the light, flocculent cirri at from 10,000 to 24,000 feet, but observations made during balloon ascents prove that clouds are capable of rising to a far more considerable altitude than was formerly supposed.

Thus, when Messrs. Barral and Bixio, in their ascent from the gardens of the Parisian Observatory, on July 27, 1850, had reached a height of 8,000 feet, they entered a cloud which proved to be fully 15,000 feet in thickness. They never even ascended to its highest point, though on approaching its limit, the blue sky was seen through an opening in the surrounding vapour; for when the height of 23,000 feet was reached they began to descend, owing to a rent which was then found in the balloon. Gay-Lussac also, in his aerial ascent to a height of 7,650 yards, observed cirrus clouds floating at a considerable elevation above him.

To Mr. Glaisher we are indebted for some highly interesting observations on the height of clouds. On June 26, 1863, he ascended with Mr. Coxwell from Wolverton on a cloudy, windy afternoon. When they left the earth, at three minutes after one, the air had the agreeable temperature of 65°. In four minutes they were 4,000 feet high, and entered a cloud with a temperature of 50°, a sudden change which caused a most painful feeling of cold. As on all previous occasions, they expected soon to break through the clouds into a flood of light, and to look down upon a heaving sea of silvery mists; but on this occasion all was dull and grey when they emerged, and they still saw clouds above them. At 9,000 feet high they heard the sighing or rather moaning of the wind, as preceding a storm, and satisfied themselves that it was in no way attributable to any movement of the cordage about the balloon, but that it was owing to conflicting currents of air beneath. Rising higher and higher, through alternate zones of rain, fog, and faint sunshine, they were now about three miles high, and still, to their astonishment, as they looked around, there were clouds below them, others on their level, at a distance, and yet more above. At 20,000 feet the sun was just visible. They were now approaching four miles high, and clouds, dense clouds, were still above them for a space of 2,000 or 3,000 feet. They met with no fog, but on passing above four miles high, their attention was attracted to a dark mass of cloud, and then to another on their level. Both these clouds had fringed edges, and were not the light cirri which might have been expected at this enormous height, but unmistakable *nimbi*. Without the slightest doubt they were both rain-clouds. Whilst looking at them, they again lost sight of everything, being enveloped in fog, whilst passing upwards through 1,000 feet. At 22,000 feet they emerged again, and were above clouds on passing above 23,000 feet. 'I still wished to ascend,' continues Mr. Glaisher, 'to find the limits of this vapour, but Mr. Coxwell knew better, and I was met with a negative, "Too short of sand. I cannot go higher—we must not even stop here." I was therefore most reluctantly compelled to abandon the wish, and looked searchingly around. At this highest point, in close proximity to us, were rain-clouds; below us, dense fog. I was again reminded that we must not stop here. With a hasty glance everywhere—above, below, all around—I saw the sky nearly covered with dark clouds of a stratus character, with cirri still higher, and small spaces of faint blue sky between them; the blue was not the blue of four or five miles high, as I had always before seen it, but a faint blue, as seen from the earth when the air is charged with moisture.



SNOW IN THE UPPER REGIONS.

'Hastily glancing over the whole scene, there were no extensive, fine, or picturesque view, as in such situations I had always before seen. The visible area was limited; the atmosphere was murky, the clouds were confused, and the aspect everywhere dull.'

During their downward journey, on passing just below three miles, rain fell pattering on the balloon. On passing below 14,000 feet, and for a space of nearly 5,000 feet, they passed through a beautiful snowy scene. There were no flakes in the air; the snow was entirely composed of spiculæ of ice, of cross spiculæ at angles of 60°, and an innumerable number of snow crystals, but distinct and of well-known forms, easily recognisable as they fell and remained on the coat. This unexpected meeting of snow on a summer afternoon was all that was needed on this occasion to complete the experience of the characteristics of extreme heat of summer with the cold of winter within the range of a few hours. On passing below the snow, at about 10,000 feet from the earth, a murky atmosphere continued till the ground was reached; indeed, so thick was the lower atmosphere, that, although they passed nearly over Ely Cathedral, and not far from it, they were unable to see it.

During this highly interesting ascent the temperature of the air was found to decrease from 65° to 18° at the highest point, which was reached in less than an hour, and to increase to 66° again on descending to the earth. Since dense rain-clouds or *nimbi* have thus been met with at an altitude equalling that of Chimborazo, we well may ask whether it will ever be possible to ascertain the limits of the light cirri which are seen floating in those upper regions of the atmosphere which even the boldest aeronaut is unable to attain.

CHAPTER XII.

RAIN.

Rain a Benefactor and a Scourge to Mankind—The Formation of Rain—The Increasing Size of Raindrops as they Fall—Enormous Raindrops in the Tropics—The Tropical Dry and Rainy Seasons—Rains of the Monsoons—Sub-tropical Rains—The Highest Annual Rainfalls—Mountains act as Condensators—Countries Remarkable for an Abundance of Rain—Distribution of Rain in Great Britain and Ireland—On the Continent—Instances of Enormous Rainfalls in Europe—Their Destructive Effects—Description of Mountain Torrents in Switzerland swollen by Heavy Rains—Large Conflagrations able to produce Rain—Professor Espy's Proposal—The Raining of Fishes—Of Frogs—Of Brimstone—Of Blood—The Supposed Marvellous Character of these Rains Explained by Natural Causes.

RAIN is both a benefactor and an enemy of man—a precious gift of the atmosphere and a terrible scourge. It nourishes and destroys; it fertilises the fields, and prevents the crops from ripening; it fills the beds of navigable streams, and inundates the land with devastating floods. It has plenty and scarcity, joy and sorrow, health and disease, hope and disappointment in its train.

Sometimes we welcome it with Longfellow—

How beautiful is the rain
After the dust and heat;
In the broad and fiery street,
In the narrow lane,
How beautiful is the rain!

How it clatters along the roofs,
Like the tramp of hoofs!
How it gushes and struggles out
From the throat of the overflowing spout.
Across the window pane it pours and pours,
And swift and wide,
With a muddy tide,
Like a river down the gutter roars
The rain, the welcome rain.

and then again we long with Coleridge for its cessation—

> O rain! that I lie listening to,
> You're but a doleful sound.

With an aching heart the husbandman sees the pitiless rain laying his corn or damaging his hay; while, at the same time—

> The sick man from his chamber
> Looks at the twisted brook;
> He can feel the cool
> Breath of each little pool.
> His fevered brain
> Grows calm again,
> And he breathes a blessing on the rain.

This wonderful phenomenon, so variable and so contradictory in its effects, so full of weal and woe, is caused by a progressive condensation of the aqueous vesicles or droplets of which clouds and fogs are composed. When a cloud comes into contact with a warmer air current, it dissolves and disappears in the serene sky, even as on a clear day the steam of a locomotive, gushing forth in thick silvery clouds, soon floats away in light, gauze-like fleeces, and then entirely vanishes from sight.

But when a cloud meets with an increased diminution of temperature, the point of saturation of the air in which it floats is still further depressed, its particles increase in size, weight, and quantity, and, congregating into larger water drops, are eventually precipitated upon the earth.

While the volume of the air mass in which the formation of rain takes place is diminishing under the influence of a cooler temperature and the condensation of its aqueous vapour, the neighbouring air strata rush in to restore the equilibrium, and increase the rainfall in proportion to their saturation with humidity. Thus, rain which is produced by air currents is, at the same time, one of their effective causes. A child of the wind, it is also a wind-creating power, and often carries in itself the conditions of its prolonged duration.

As they descend, the raindrops increase in size, either by several of them joining or by condensing aqueous vapour on their surface while traversing warmer air-strata. Thus every raindrop that wets the ground is derived not only from the high cloud which gave it birth, but from the whole intermediate atmosphere. We consequently find a great difference in the rainfall which takes place simultaneously on the top or at the foot of a hill, or even of a high building. On the roof of the Imperial Schloss at Berlin, for instance, the mean annual quantity of rain is only 18 inches, but on the pavement below it amounts to 20.

In the Parisian Observatory it has likewise been found, as the result of a series of observations continued during many years, that only 50 centimetres of rain fall upon the terrace of the building, which is 28 metres high, while during the same period the rainfall in the courtyard amounts to 56 centimetres, or above one-ninth more.

The growth of the rain as it falls explains how the water-drops drizzling from fog are much smaller than those which proceed from clouds; for, as fogs are nearer to the surface of the earth, the drops fall from an inconsiderable height.

As the clouds in the tropical zone are very high, and, moreover, the warm ascending air currents, whose cooling occasions rain, contain a large quantity of aqueous vapour, the raindrops of an equatorial shower frequently measure as much as an inch in thickness, and occasion pain when falling on the naked skin. For the same reason we find rain descending in much heavier drops in summer than in winter, when the clouds are generally very low. The drops then remain so very small that the wind easily drives them along in a horizontal direction.

Though raindrops generally grow as they descend, still it sometimes happens that small drops falling from a considerable height diminish in size, or even completely evaporate as they traverse warm and relatively very dry atmospherical strata. Thus in summer it is not uncommon to observe grey streaks descending from the lower surface of a cloud, which either do not reach the ground at all, or only after having cooled the lower air strata through which they pass. Under these circumstances, a rainbow may sometimes be seen unaccompanied by an actual fall of rain.

Another very remarkable phenomenon is that of rain without clouds, an occurrence which the ancients considered as a prodigy. In the island of Mauritius this phenomenon is sometimes noticed in the seasons when the south-east winds blow. About evening time, while the weather is most beautiful, a very fine rain occasionally descends; and Sir J. C. Ross relates that in the South Atlantic it rained on one occasion for upwards of an hour, while the sky was altogether free from clouds. 'The night was clear,' says a Genevese naturalist, 'the stars were shining with their accustomed brilliancy, when a shower of rain, consisting of large, lukewarm drops, fell during six minutes upon the town.' A similar rain was observed at Constantine, in Algeria, about noon, the sky being all the time of a splendid blue. Arago was told both by Humboldt and Beechey that they had witnessed the same phenomenon in tropical countries, and believes it to result from particles of ice which, having been formed in the higher regions, melt and grow as they descend.

A very fine rain, called *serein* in France, which has more the characteristics of falling dew, as it appears a short time after sunset, when the sky is clear, has been attributed to the cold resulting from the radiation of the air. It is not the air, however, but the aqueous vapour in the air, which, by its own radiation, chills itself, so that it condenses into *serein*.

The formation of rain, like that of clouds, takes place under various circumstances. It is either produced by the vertical ascent of a warm air current, whose moisture condenses as it reaches the higher regions of the atmosphere, or when the moist and warmer air of the equatorial stream flows horizontally from a lower to a higher latitude, and consequently deposits its humidity as it gradually advances into colder regions, or when air currents of unequal warmth commingle, and consequently undergo a diminished power of solution.

The rains caused by the vertical ascent of warm air currents are most frequent in the torrid zone, where they appear at stated times, with such regularity, that the Indians of the Orinoko divide the year into a season of clouds and a season of sun. In the belt of calms, where—

All in a hot and copper sky,
The bloody sun at noon,
Right up above the mast does stand
No bigger than the moon,

and causes the rarefied air to rise in mighty columns undisturbed by lateral movements of the atmosphere, daily showers occur, accompanied with terrific electrical explosions. At the commencement of the wet season the diurnal rains begin in the morning between nine and ten o'clock, and last till about three or four ; farther on, they begin at eleven, then at one or two, and so on until they suddenly cease. In the tropics, it seldom rains during the night, and at all seasons of the year the sun rises in a cloudless sky. Beyond the girdle of the calms, in the regions of the trade winds, which are constantly conveying a drier air from higher latitudes into the tropical zone, the weather meanwhile is constantly serene. But as the belt of calms, with its vertical air-columns, is perpetually shifting, either towards the north or the south, according to the position of the sun, many places which had been previously under the influence of the trade winds are periodically included in the calms, and a rainy season follows after one of drought. Thus the sun opens or closes the sluices of the skies, as with the changing seasons he approaches or withdraws from the tropic of the Cancer or of the Capricorn. But in the equatorial regions the sun passes twice through the zenith of each spot, with the exception of the places situated at their extreme verge, where its vertical position takes place only once a year. Hence there are generally two rainy seasons following upon each other, after shorter or longer intervals, merging into one towards the tropics, and most widely separated in the vicinity of the equator, where two rainy and two dry seasons appear in distinct succession.

As may easily be imagined, the influence of these periodical changes upon tropical vegetation is no less marked than that of the winter and summer of the higher latitudes. 'When day after day,' says Humboldt, 'the sun rising and setting in a cloudless sky pours his burning rays upon the thirsty savannas of Venezuela, the calcined herbage presents the monotonous aspect of an interminable waste. Like the ocean, its limits melt in the hazy distance with those of the horizon; but here the resemblance ceases, for no refreshing breeze wafts coolness over the desert, and comforts the drooping spirits of the wanderer. At length, after a long drought, when all Nature seems about to expire under the want of moisture, various signs announce the approach of the rainy season. The sky, instead of its brilliant blue, assumes a leaden tint from the vapours which are beginning to condense. The black spot of the 'Southern Cross,' that most beautiful of constellations, in which, as the Indians poetically fancy, the Spirit of the Savannah resides, becomes more indistinct as the transparency of the atmosphere diminishes. The fixed stars which shone with a quiet planetary light, now scintillate even in the zenith.

Like distant mountain chains, banks of clouds begin to rise over the horizon, and, forming masses of increasing density, ascend higher and higher, until at length the sudden lightnings flash from their dark bosom, and with the loud crash of thunder the first rains burst in torrents over the thirsty land. Scarcely have the showers had time to moisten the earth, when the dormant powers of vegetation begin to awaken with an almost miraculous rapidity, and the dense surface of the parched savannah changes as if by magic into a carpet of the most lively green, enamelled with thousands of flowers of every colour.

Similar changes are produced in Africa, on the banks of the Zambesi, by the first rainfalls. 'The air,' says Dr. Livingstone, 'becomes cleared of the smoky-looking haze, and one sees to great distances with ease; the landscape is bathed in a perfect flood of light, and a delightful sense of freshness is given from everything in the morning before the glare of noon overpowers the eye. The young foliage of several trees, more especially on the highlands, comes out brown, pale red, or pink, like the hues of autumnal leaves in England, and as the leaves increase in size, they change to a pleasant fresh light green; bright white, scarlet, pink, and yellow flowers are everywhere, and some few of dark crimson, like those of the kigelia, give warmth of colouring to Nature's garden. Many trees, such as the scarlet erythrina, attract the eye by the beauty of their blossoms. The white full bloom of the baobab, and the small and delicate flowers of other trees grouped into rich clusters, deck the forest. Insects of all sorts are now in full force, myriads of wild bees are busy from morning till night, brilliant butterflies flit from flower to flower, and, with the charming little sunbirds, never seem to tire. Multitudes of ants are hard at work hunting for food, or bearing it home in triumph. The winter birds of passage, such as the yellow wagtail, and blue drongo shrikes, and other kinds, have come; the brown kite with his piping like a boatswain's whistle, the spotted cuckoo with a call like 'pula,' and the roller and hornbill with their loud high notes, are occasionally distinctly heard, though generally this harsher music is half drowned in the volume of sweet sounds poured forth from many a throbbing throat, which makes a South African Christmas seem like an English May.'

Thus the rainy season is in all the tropical lands where it takes place the source of plenty, and of the most luxuriant vegetation; but at the same time it causes great personal discomfort to their inhabitants. Accustomed to a copious perspiration, which mitigates the effects of heat, they suffer severely in an atmosphere which, saturated with humidity, prevents the transpiration of the skin. Malaria rises from the swampy lowlands, and malignant fevers, particularly dangerous for strangers, make their appearance. The timber and furniture of the houses expand in consequence of the humidity of the atmosphere, all iron utensils rust, the salt liquefies, the grain germinates, and meat becomes putrid in a very short time. A host of insects and nauseous reptiles, driven from their hiding places, seek a refuge in the dwellings of man. Numerous species of toads, centipedes, scorpions, and snakes, crawl into the passages and rooms. At night it would be dangerous to move a step without a light, for fear of trampling upon some creature whose bite or sting may be mortal. Everything one touches or puts on must first be carefully examined, for some poisonous vermin may be concealed in a boot, or lurking in a sleeve, or hiding among the bed-clothes.

Like the tropical rains caused by the ascending air current in the belt of calms, the rains of the monsoons likewise take place when the sun attains its highest position. Thus in summer, when the wide lands of south-eastern Asia are glowing with a torrid heat, the rarefied air, as it rises into the higher regions, forces the south-east trade wind or monsoon to obey its influence, and completely diverts it from its usual course. Laden with the emanations of the Indian Ocean, the south-west monsoon then strikes against the Western Ghauts, and, forced by these mountain-barriers to ascend into colder regions, discharges its humidity in torrents of rain. This takes place from May till September, but when from the sun's declining to the south, the Asiatic continent loses its high temperature, the north-east trade wind once more resumes its sway, and brings rain to the Eastern Ghauts. Similar deflections from the usual course of the trade winds produce analogous effects in other parts of the torrid zone. Thus the sea monsoon which prevails during the summer months on the coast of northern Guinea, and owes its existence to the intense heat generated at that time in northern Africa, carries a rainy season over the land as far as the eighteenth or nineteenth degree of northern latitude, and fertilises a vast extent of country, which otherwise would probably be as naked and barren as the Sahara.

The tropical seas are the chief source from which the atmosphere derives its moisture, for though evaporation takes place in every part of the world, it is nowhere more active than in the equatorial ocean. In the latitude of the Azores, Mr. Hunt found by measurement that the annual evaporation insensibly consumes a sheet of water more than three feet thick. Nearer to the region of the trade winds, in the latitude of Madeira, the amount of evaporation increases to double the quantity, so that we can form some idea of the immense volumes of water which the tropical sun is constantly raising from the surface of the equatorial seas. When we further consider that water predominates in the torrid zone, while the greater part of the northern temperate regions is occupied by land, it is evident that most of the moisture which the west and south-west winds precipitate upon our fields is derived from the tropical ocean. The countries where these warm and damp equatorial air currents, or recurrent trade winds, first impinge upon the surface of the earth on their progress to a higher latitude, form the regions of the sub-tropical rains, which, conjointly with the belt of calms and the trade winds, move alternately northward and southward, according to the position of the sun. In winter, when the great luminary is farther removed from the northern hemisphere, they descend as far south as the Azores and the Canaries, which consequently have their rainy season during the winter months. But as the sun advances towards the north, the recurrent trade winds follow it in the same direction and descend upon the southern coasts of Europe, which have consequently their heaviest rainfalls in spring, and particularly in autumn, when the sun is again verging towards the south.

In summer, when the whole system of the trade winds has attained its most northern limits, the recurrent air-streams first reach the earth in Central Europe, where, consequently, most rain falls at this time of the year. The frequent rains which generally take place in Germany towards the end of June, are also partly owing, according to Dove, to the warmth generated by the sun in the interior of the continent while the temperature of the sea remains considerably cooler. Hence colder maritime air currents frequently mingle with the warmed continental air, and give rise to abundant showers.

As the quantity of rain depends upon that of the aqueous vapour contained in the atmosphere, and this, in its turn, is generated in greater abundance under the influence of warmth, the highest annual rainfalls have consequently been observed in the tropical zone, wherever peculiar local circumstances favour the condensation of moist and tepid air currents. In the equatorial forest regions of America they amount to at least 100 or 112 inches, and in Guadaloupe have even been found to measure as much as 274 inches. Of the enormous masses of water which the tropical rains pour upon the earth, we Europeans can hardly form an idea. 'The September rains in Porto Rico,' says Flinter, 'are like water poured through a sieve;' and another traveller, speaking of the West Indian islands, mentions the rain as falling not in drops but in strings of water. 'During our visit to the small island of Gorgona (on the South Sea shore of New Grenada),' says Dampier, 'we made some chocolate, which we were obliged to drink standing. The rain was so strong that, however much chocolate we drunk, our calebasses remained constantly half full, and some of us even swore that it was impossible to drink as much as it rained.'

'Old seafaring men,' says Maury,[1] 'mention such heavy and constant rains in the region of calms that they have scooped up fresh water from the surface of the sea.'

Captain Roussin writes in a letter from Cayenne, February 28, 1820, 'from the 1st to the 24th of February, twelve feet and seven inches of water have fallen from the atmosphere. I have convinced myself that in the night from the 14th to the 15th, from eight o'clock in the evening till six in the morning, ten inches and a quarter of rain-water fell into a vessel which I had placed in the middle of my yard.'

According to the observations collected by Colonel Sykes, on the slope of the Ghauts and Cossia Hills in India, the rains at the setting in of the south-west monsoon are probably still more abundant. On September 2, 1833, 13·06 inches of rain fell at Mahabuleschwar; and in the months of June, July, and August, several instances occurred of 11·32, 12·76, and 12·69 inches. In Uttray Mullay, General Cullen observed, on October 14, 1845, no less than 15·1 inches, and on December 11 of the same year, 11·4. In Cherraponjee (4,500 feet high, 25° 17′ N. lat., and 91° 44′ E. lat.), 147·2 inches of rain fell during the month of June. Now the annual rainfall on the south-west coast of England averages from about 23 to 46 inches,[2] so that as much rain poured down upon Cherraponjee in that single month as during three years at Penzance or six at Bristol.

During his travels in the province of Minas, in Brazil, Tschudi witnessed a rainfall of unexampled violence. 'I have often,' says the distinguished traveller, 'seen enormous masses of rain fall from the skies, but only for a short time, while in this instance the rain lasted full seven hours. Neither before nor since have I ever witnessed a similar spectacle. After a couple of hours it was truly awful. The terrified inhabitants feared the destruction of their village. Over every slope torrents of water poured down, constantly increasing in size and violence. In my apartments, in the best house of Capelhinha, not a single spot remained dry; the water that streamed in through the roof flowed out again through the door. From time to time a flash of lightning illumined the dark rooms, and a clap of thunder silenced for a moment the roaring rain-streams. From hour to hour we kept anxiously waiting for the end of this terrible deluge, which I can hardly think of even now without shuddering. All extraordinary destructive natural phenomena, against which it is impossible for man to strive, of which he is condemned to be the passive spectator, make an uncommonly deep and lasting impression on his mind. I am convinced that pluviometrical observations made on this day at Capelhinha would have furnished a result perhaps without a parallel in the annals of meteorology.'

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[1] 'Sailing Directions,' sixth edition, p. 122.

[2] Penzance, 45·945; Bristol, 23·25.

On the other hand, the rainfall in other parts of the equatorial zone is far inferior to that which takes place in the temperate regions. The countries suffering from these exceptional droughts are chiefly those which, as the sun advances, are not admitted into the region of calms, and, as it recedes, do not quit that of the trade winds, and, consequently form a zone, in which sometimes several years elapse without rain. In Cumana frequently not two inches of rain fall during nine months, from December till September. At La Guayra and the neighbouring island of St. Margarita, some drops of rain only fall in October and November. At Ambukol, near Dongola, in Nubia, the rain only fell five times in the years 1823 and 1824; at Tatta, on the eastern bank of the Indus, no rain fell during three years; and the Canary Islands remain sometimes two full years without rain. Though, in general, the quantity of rain decreases on advancing from the tropics to the poles, these few examples sufficiently show that the mere geographical position of a place as to latitude is far from giving us the measure of its annual rainfall, which frequently depends upon many other circumstances, such as the prevailing winds, the mountainous or level configuration of a country, its being naked or covered with forests, its vicinity to the sea, or its situation in the interior of a continent.

In all parts of the world, mountains are the chief condensators of atmospherical moisture. Warm currents of air which sweep unchanged over the plains at once precipitate their vapours as soon as they reach more elevated regions.

Thus, in summer, a southerly wind frequently obscures the Alps for days together with dense clouds and abundant showers of rain, while, at the same time, it leaves the warm plains of Lombardy in the possession of the brightest sunshine. 'The atmospheric change was wonderful,' says Professor Tyndall[1] (who had been driven from Switzerland into Italy by the perfectly unmanageable weather of July, 1866), 'and still the clear air which we enjoyed below was the self-same air which heaped clouds and snow upon the mountains. It came across the heated plains of Lombardy charged with moisture, but the moisture was in the transparent condition of true vapour, and hence invisible. Tilted by the mountains the air rose, and as it expanded it became chilled, and as it became chilled it discharged its vapour as visible cloud, the globules of which swelled by coalescence into raindrops on the mountain flanks, or were frozen to ice-particles on their summits, the particles collecting afterwards to form flakes of snow.'

In consequence of the condensating influence of mountains, the slopes and valleys facing the moist and warm sea winds have a much greater rainfall than those which are situated on the opposite side. Thus, along the southern foot of the Alps, we find the annual rainfall amounting at Brescia to 47 inches, at Venice to 35, at Vicenza to 41, and at Cerciventa to 75; while on the northern declivities Geneva has only 30 inches, Zürich 31, Munich 32, and Vienna 17.

The large annual rainfall (104 inches) observed at Coimbra, in Portugal, is entirely due to the amphitheatre of mountains which girdles the town and intercepts the moist sea wind. The south-west monsoon, which pours such a deluge of water upon the western slopes of the Ghauts, affords but the scant supply of 23 inches to Poonah, which is situated on the plateau of the Deccan, and loses so much of its moisture on reaching the enormous mountain barrier of the Himalaya, that it is almost completely dry on reaching the steppes of Tartary.

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[1] 'Macmillan's Magazine,' March, 1869.

In extra tropical South America, we find a remarkably rainy climate on the western side of the Cordillera, which is exposed to the prevailing sea winds, while the countries situated to the east of that high mountain chain suffer from drought, or are even completely rainless. Thus, on the island of Chiloe, one can but rarely enjoy a clear prospect of the forest-crowned hills, for the sky is almost always clouded, and to have a week of fine weather is something wonderful. During the winter the sun scarcely ever makes his appearance, but there is occasionally a fine day in summer, when Osorno, the Corcovado, and the other high snow peaks of the Cordillera, stand out for a few hours in bold relief upon a blue sky, but soon again disappear behind a dense mantle of vapour. East Patagonia, on the contrary, the enormous plain rising in terraces from the borders of the Atlantic to the foot of the Cordillera, is a treeless waste, in consequence of the extraordinary aridity of the prevailing west winds which have been deprived of their moisture on crossing the mountains. In the same latitudes as those of Chiloe and the other rain-abounding and forest-clothed islands of the west coast, we find here a perennial drought which reduces vegetation to the scantiest proportions.

In Europe, the south-west and west coast-lands, and more particularly the hill and mountain ranges facing the recurrent equatorial air-streams, likewise condense a considerable part of their moisture, and are consequently more abundantly supplied with rain than the interior of the continent or the countries situated to the east.

In Ireland, Cahirciveen, Westport, and Castletownsend, situated on the south-west side of high mountains, had 59·4, 45·9, and 42·5 inches of rain in 1851; while Portarlington, on the Slieveboom, and Killough on the north-east side of the Mourne Chain, had only 21 and 23·2 inches during the same year.

The following table of the greatest and the least annual rainfalls which are known to have occurred in Great Britain likewise shows us the immense difference caused by a position averted from or facing the equatorial current:—

		Inches
England.	The Stye at the head of Borrowdale, in Cumberland	198·19
	Seathwaite, Cumberland	150·11
	Longdale ,,	118·50
	North Sunderland	20·09
Wales.	Rhiwbrifdir	187·55
	Festiniog	85·51
	Great Orme's Head	27·96
Scotland.	Upper Glencoe	121·50
	East Linton, Haddington	15·77

The enormous rainfalls at the Stye or Seathwaite,[1] appear still more extraordinary when it is considered that in 1869 the mean rainfall of the whole kingdom amounted to 34·96 inches, and in the five years from 1860 to 1865 to 35·21.

In continental Europe we find a similar decrease of rain on advancing from the coast lands to the interior. While in Holland and Belgium the annual rainfall amounts in many places to more than 31 inches, it decreases in Westphalia to 25. On the coasts of Brittany and Normandy we meet with an annual rainfall of 25 inches, while in Paris the quantity is reduced to 21.

The difference between the western and eastern coasts of Scandinavia is still more remarkable, where, near the town of Bergen, the almost tropical annual rainfall of 85 inches occurs, while Stockholm receives no more than 20 inches. It is evident that this enormous difference results from the mild south-west winds, which, laden with the vapours arising from the warm Gulf Stream, condense their moisture in almost perpetual fogs and rain, all along the coast of Norway, up to its final termination at the North Cape (71° N. lat.), and are comparatively desiccated after crossing the high mountain chains which separate Norway from Sweden. On the other hand, the easterly or polar winds, sweeping over a vast extent of continent and narrow seas, can bring but a small quantity of rain to the eastern coasts of Scandinavia.

In Germany, where the rainfall also generally diminishes on advancing towards the east, the condensing influence of mountains is very perceptible. The rainfall, which in Prague amounts to 15 inches, gradually increases along the southern foot of the Riesengeberge to 33 inches. The isolated Hartz Mountains are such mighty condensators of humidity that the annual rainfall at Clausthal and on the Brocken amounts to more than 50 inches, while the mean quantity at Berlin is no more than 23 inches.

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[1] G. T. Symons, 'On the Distribution of Rain over the British Isles during the year 1869, as observed at about 1,500 Stations in Great Britain and Ireland.'

Though, upon the whole, the rainfall is found to diminish on advancing from the equator to the poles, the number of rainy days generally increases in the opposite direction. On an average, the south of Europe has 120 rainy days in the year, Central Europe 146, and the north of Europe 180, where many days of drizzling fog hardly produce as much rain as one single hour of a tropical thunderstorm.

But even in temperate climates we have many examples of rainfalls far exceeding the ordinary measure. On June 4, 1839, 4 inches of rain fell at Brussels, as much as the average fall of a whole month in Germany; and on May 20, 1827, a thunderstorm at Geneva precipitated 6 inches of rain.

The northern coasts of the Mediterranean seem to be particularly liable to prodigious rainfalls. In 1827, 15½ inches of rain fell at Montpellier from September 23 to 27, and at Viviers, on September 6, 1801, more than 13 inches within 18 hours.

The fall of 30 inches of rain within 24 hours took place at Genoa on October 25, 1822. An assertion to this effect having appeared in a Genoese newspaper, the editors of the 'Bibliothèque Universelle de Génève' wrote immediately to make the necessary enquiries as to an observation so unprecedented. The reply which they obtained from M. Pagano, an exact observer, is given at length in this journal:—

'Two wooden pails, nearly cylindrical, one of them 24 inches and the other 26 inches high, which had been used for some experiments on the vintage, had remained empty in my garden. The rain of Friday, October 25, had not yet ceased when they were entirely full.' M. Pagano then proceeds to state on what grounds he infers that 4 inches more of rain fell after the largest vessel was filled, making a total of 30 French (32 English) inches, and then adds a statement of several facts to show that the effects of this deluge in the neighbourhood bore a proportion to the magnitude of the cause. M. Arago, quoting the result, adds, 'This unprecedented result appeared doubtful to all meteorologists (an error of the press was suspected), but M. Pagano's account established the fact beyond contradiction.'

This *local* deluge (for its range seems to have been very limited) is nearly rivalled by a similar fact recorded in the south of France by an experienced observer, M. Tardy de la Brossy, of Joyeuse, Département de l'Ardèche. M. Arago, who records the observation, and gives it the weight of his authority, does so in these words:—

'The 9th October, 1827, in the interval of twenty-two hours, twenty-nine inches and three lines of water fell in the town of Joyeuse; I write the result in full letters, so as to remove all doubt about a fault of impression.'

A shower hardly less surprising took place at Catskill (U. S.), when Mr. Durght ascertained that on July 26, 1819, between 3·30 P.M. and 11 P.M., that is, in 7½ hours, there fell into an empty barrel, placed in an open space, 18 inches of water. A tub, 15½ inches deep, was filled before sunset.

When such enormous masses of water suddenly deluge the earth, their swelling floods rival the fury of the wind or the devouring conflagration in the ruin and desolation they spread around.

On June 16, 17, and 18, 1872, violent storms occurred in almost all parts of England, accompanied with torrents of rain, which inundated large tracts of country and caused immense damage to property. In Newcastle, Liverpool, Birmingham, and many other towns, the streets were flooded. In one of the main thoroughfares of Barnsley where four roads meet, the water was fully four feet high, so that persons had to be taken across in carts, waggons and cabs. In the lower part of the town the water inundated the lower rooms and cellars to a depth of several feet. All the power-loom factories were entirely stopped, the water having reached the boilers, so that the latter could not be kept going. In the Henley district, the roads in several instances were some four, five, and six feet under water, and many of the inhabitants were compelled to take refuge in the upper parts of their dwellings. In Bradford, the streets flowed deep with water, which gave them the appearance of rapidly flowing rivers. This was especially the case in the centre of the town, where the cellars of merchants and shopkeepers were flooded, and great damage was done to goods. At Northwich, the river Weaver overflowing its banks, the High Street was inundated to the depth of four or five feet. Diluvial rains, still more destructive, occurred in July; on the 13th, the rain fell in Manchester so heavily for more than thirteen hours, that occasionally it might have been imagined that a waterspout had broken over the city. The flood-water of the river Medlock rushed through a cemetery, and, destroying the graves and dashing several hundred coffins to pieces, carried the released bodies down the stream. Some of these ghastly mementoes of the power of rain floated down through Manchester into the Irwell, and thence into the Mersey; others again, into Phillip's Park and into adjoining cellars and gardens. In many parts of Yorkshire and Lancashire, bridges were destroyed, factories, houses, mills considerably damaged, the outlying crops washed away, and several people drowned in the swollen streams.

INUNDATION IN STREETS OF TOWN.

All these devastations, however, appear insignificant when compared with the dreadful effects of the rainspouts, which, a few weeks before, had covered all north-western Bohemia with ruin and desolation. The inundation began near Rakonitz, where the rain fell in such torrents as to bear down the dams which confine some large ponds in the neighbourhood, and to set the whole town under water.

The Rakonitz brook, suddenly swollen by this enormous influx, rolled from the north its turbulent waters into the Beraun, causing that river to rise at once twelve feet. Meanwhile, the rain was pouring down upon all the mountains and gorges, which discharge their waters into the Beraun from the south, so that in a short time its whole valley, and that of the Lower Moldau, offered the spectacle of an agitated sea. Whole villages were swept away, thousands of people perished, and the destruction of property amounted to many millions of florins.

During a thunderstorm which discharged itself over Odessa, on June 8, 1869, three inches of rain fell in less than an hour. The floods, not being able to find an outlet through the gutters, inundated the streets. The main drain, which runs under the Quarantine Square, was unable to resist the influx, and was almost entirely swept away. The water tore up the large granite slabs of the pavement, and hollowed out a deep gully, through which it poured tumultuously into the sea. Several heavy waggons, laden with goods, were carried away by the torrent, and their teams drowned. Many persons shared the same fate. In the suburbs eighty-seven houses were totally destroyed.

The torrents, which come raving down the precipitous flanks of the Alps after heavy rainfalls, are the dread of the Swiss peasant. Even in the plains, a swollen river, rolling its turbid waters through the fields, is an object of fear and apprehension, but how much more terrible is the resistless fury of the wild mountain-stream. After a period of drought its stony bed is either completely dry or merely intersected by narrow threads of water, and the stranger wonders how the clear rivulet, flowing on so quietly, can ever attain such gigantic proportions; but in the autumn, when the warm Fönwind, with its diluvial rains, melts and washes down the recent snowfalls of the mountains, the scene changes in a few hours, and the peaceful lamb becomes a devouring lion.

Nothing, indeed, can be more terrible than these water-demons when in full activity. Tearing along with them rocks, trees, boulders, sand, and mud in their mad career, and frequently thrown out of their bed by the obstructions they meet with in their course, they seek a new passage over the meadows and cultivated fields as they rush precipitously into the vale below. The thundering noise of their fall rings far and wide, and fills the whole neighbourhood with horror and dismay. Whoever is able to carry a pole, shovel, or a hoe, hurries to the banks of the torrent to remove as much as possible any impediment that might divert it from its course; and the shouts and lamentations of the men mingle with the crashing of rocks and the roaring of waters. Whoever has witnessed this dreadful scene on a stormy night can never forget it. The finest meadows are not seldom buried in a few hours under mounds of rubbish ten or fifteen feet deep, and converted into stony deserts of sand, mournfully overtopped by the crowns of fruit trees. Not seldom the torrent, suddenly altering its course, tears down houses and stables, and destroys in a moment the property of many families. These devastations, which it is

OVERFLOWING MOUNTAIN TORRENT TEARING AWAY SWISS CHALET.

often impossible to prevent, have already ruined many a fine Alpine vale, and seem to be increasing in spite of the strong dykes which in many parts are carried high up into the mountains.

When we bear in mind that after continuous heavy rains, extending over large alpine regions, hundreds upon hundreds of such torrents come rushing down from every ravine, and finally unite their swelling floods in one vast sheet of water, we cannot wonder at the dreadful inundations which a few years back devastated the broad valleys of the Reuss and Upper Rhine, and caused a loss of property amounting to many millions of francs.

Large conflagrations, by causing warm and moist air currents to ascend to a considerable height in the atmosphere, where they become condensed by the cold, are able to produce rain. In the United States, the setting fire to the prairies and sawgrass-ponds gives opportunities for making the experiment on a grand scale. In ponds of this description, the green grass at the top shoots up from five to six feet in height, and when the region has not been for some years swept clear by fires, the dead and dry growths of preceding seasons accumulate under the latest growth, and are often found there from three to four feet in depth. They are exceedingly inflammable, and when lighted in dry weather burn with frightful rapidity and violence.

The rain-producing effects of their conflagration once gave Captain Mackay, an American land surveyor, an excellent opportunity for astonishing some superstitious negroes, and making them believe that he could call together the clouds and compel them to discharge their contents. 'When our party,' writes a witness of the scene, 'were all gathered at the halting-place on the confines of a formidable sawgrass-pond, which, being surrounded by a cypress swamp, had probably never yet been set fire to, complaints of the extreme heat went round, and all unanimously agreed that a more confined and oppressive day had never been known to them. To these complaints the usual wishes for a "little breath of air" and "a few drops of rain" succeeded. "Cut through this pond," exclaimed the Captain, "and I'll bring you more than a few drops of rain; I'll give you a plentiful shower, and a breeze, too, that shall wake you up. Come, boys, cut away; and when you've done, you shall wash off the dust in a cold bath from the skies." They stared up and around; not a cloud as large as a man's hand was to be seen; and they looked back at the Captain with a good-natured grin of incredulity. "Ha! ha! Captain make cloud out o' nuffin; he! he! Captain bring water all dis way from the sea; ho! ho!—ha! ha!—he! he!" Whereupon the Captain affected to be very indignant. To hasten his victory, I ordered the grass to be set on fire. The flames soared forthwith above the tallest trees, and a dense volume of smoke mounted upward spirally. As the smoky column broke, and the cloud began to form, the Captain traced a large circle in the sand around him, and placed himself in its centre, making fantastic figures and forming cabalistic phrases out of broken French. Still was the cloud unnoticed; all eyes were riveted upon the Captain, who stood gazing at the earth, and shaping outlines of devils there. At this juncture came a roll of distant thunder; every glance instantly turned upward; a cloud was spreading there; the thunders increased; the lightnings flashed more vividly; the knees of the negroes shook together with alarm; already was the rain descending, and in torrents, though the clear sky could be seen in all directions under the cloud. The Captain meanwhile maintained his mystical attitude, and continued his wild and extraordinary evolutions. Some of the whites who were in the secret of the hoax fell upon their knees, and were imitated by the negroes, who, their fears augmenting as the storm grew fiercer, with clasped hands fastened upon the Captain a stare of awe and deprecation.' The experiment has, indeed, been so often and so successfully tried, particularly in Florida, where many farmers are in the habit of setting fire to the dry grass at the time they plant their corn, to produce rain, that Professor Espy[1] proposes to try the principle on a vast scale, so as to benefit the whole country.

As all rains in the United States travel to the eastward from the place of beginning, and as rains and snows in the winter are of great length north and south, and comparatively narrow east and west, and of course travel side foremost, the sanguine meteorologist thinks it highly probable that if masses of timber, to the amount of forty acres for every twenty miles, were prepared and fired simultaneously every seven days in the summer, on the west of the United States in a line of six or seven hundred miles long from north to south, a rain of great length north and south would commence on or near the line of fires, then travel towards the east side foremost, and not break up until it reached far up into the Atlantic Ocean. This rain would be general over the whole country; not last longer than a few hours at any one place; would prevent tornados and destructive floods as well as injuriously low waters; would put an end to all epidemic diseases originating from droughts and inundations; greatly increase the proceeds of agriculture, and promote the general health and happiness.

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[1] Professor Espy's 'Fourth Meteorological Report,' p. 33.

Rain spreads terror and dismay not only when it rushes down in overwhelming floods; it sometimes also fills the superstitious mind with dread by its being casually mixed with various extraneous animal, vegetable, and mineral substances.

Phenomena of this kind are frequently mentioned by the Roman authors, who, instead of inquiring into their natural causes, considered them as prodigies, while our more critical times have often fallen into the opposite extreme, and altogether denied their existence. There can, however, be no doubt of the well-ascertained fact that fishes, for instance, have not seldom descended in showers at a considerable distance from their native element. At Apin, near Edinburgh, the attention of the people was attracted by a rain of this description, which took place in 1817. Many thousands of herrings, from one and a half to three inches long, were seen sprawling on the ground. Whoever considers the enormous power of the wind on the tempestuous coasts of the North Sea, and the incalculable number of herrings which periodically enter the friths for the sake of spawning, will easily account for the phenomenon without ascribing it to any preternatural cause.

In France, the streets of a town at some distance from Paris, after a terrible hurricane in the night, which tore up trees and blew down houses, were found in the morning covered with fishes of various sizes. Nobody doubted that they had fallen from the clouds; nor did the absurdity of fish of five or six inches long being generated in the air at all startle the people or shake their belief in the miracle till they found upon inquiry that a very well stocked fish-pond, which stood on an eminence in the neighbourhood, had been blown dry by the hurricane, and only the great fish left at the bottom of it, all the smaller fry having been tossed into the streets.

Insects and caterpillars are, of course, still more easily carried along by the wind, or else, after a heavy rain, they crawl out of their hiding-places in unusual numbers, circumstances which easily account for their supposed preternatural descent from the clouds.

In Italy the raining of frogs is very frequent, and it is not uncommon to see the streets of Rome swarming both with young frogs and toads in an instant in a shower of rain, though there was not the least appearance of them before. As a confirmation of their aerial birth, it is even stated that they have actually been seen to fall through the air down upon the pavements. This seems a strong circumstance in favour of the marvellous view of the subject, but when strictly examined it comes to nothing; for the frogs that are seen to fall are always found dead, lamed, or bruised by the fall, and never hop about like the rest; nor is their descent ever witnessed except near the walls of houses, from the roofs and gutters of which they have accidentally slipped down. The appearance of the frogs after a rain is easily accounted for by the circumstance that during a long-continued drought they remain in a state of torpor in holes and coverts, and all that the rain does is the enlivening them, giving them new spirits, and calling them forth to enjoy the element they delight to live in. Theophrastus, the greatest of all the naturalists of antiquity, was fully aware of the true cause of their spontaneous appearance; but the Italian philosopher Redi was the first who placed it beyond all doubt. Dissecting some of the new-appearing frogs, he found in their stomachs herbs and other half-digested food, and openly showing this to his credulous countrymen, asked them whether they thought that Nature, which engendered, according to their opinion, these animals in the clouds, had also been so careful as to provide them with celestial grass for their food and nourishment?

The raining of stones or dust is caused either by hurricanes or by the eruptions of volcanoes, which hurl a vast quantity of ashes and cinders to an immense height in the air. These light, half-calcined materials, being hurried away by the impetuous winds which usually accompany volcanic explosions, sometimes fly to immense distances, and, falling in places where the inhabitants know nothing of the occasion, cannot but be supposed by the vulgar to fall on them from the clouds.

After a heavy rain the ground is sometimes found covered with a fine, yellow dust, which easily takes fire, and although when burning it has none of the characters of sulphur, has not seldom been supposed to be that mineral by the ignorant multitude, and considered as a token of divine wrath. This so-called brimstone is, however, merely the innocent pollen of various plants which has been carried away by the wind, and then falls down with the rain. The plants which furnish it vary, of course, with their time of flowering. According to Schmieder, it proceeds in March or April from the alder and hazel-nut; in May or June from the beech, the juniper, and the pine; in July, August, and September from *Lycopodium clavatum*, *Typha angustifolia*, and different species of *Equisetum*, or horse-tail. When, after a heavy rain, ponds are found covered with yellow powder, these plants always bloom in the neighbourhood. In the woods, it is always most abundant in places exposed to the wind. 'On the afternoon of June 11, 1854,' writes Dr. D. P. Thomson, 'the wooded part of Morayshire appeared to smoke, and, for a time, fears were entertained that the fir plantations were on fire. A smart breeze suddenly got up from the north, and above the wood there appeared to rise about fifty columns of something resembling smoke, which was wreathed about like waterspouts. The atmosphere now calmed, and the mystery was solved, for what seemed smoke was in reality the pollen of the woods.'

In Silesia, after a great dearth of wheat in that country, there happened a violent storm of wind and rain, and the earth was afterwards covered in many places with small round seeds. The vulgar cried out that Providence had sent them food, and that it had rained *millet*; but these were in reality only the seeds of a species of *Veronica*, or Speedwell, very common in that country, which, being just ripe at that time, the wind had dislodged from their capsules, and scattered about. It was once said to rain wheat in Wiltshire, and the people were all alarmed at it as a miracle till Mr. Cole showed them that what they took for wheat was only the seeds or kernels of the berries of ivy, which, being then fully ripe, the wind had torn from the sides of houses and trunks of trees to which the ivy that produced them was attached. In 1804, however, a real rainfall of wheat took place in Andalusia, which had been carried by a hurricane across the Straits of Gibraltar from a thrashing-floor at Tetuan; so that by this strange atmospherical freak some Spanish peasants gained a small harvest which had cost them neither seed nor trouble.

The supposed raining of *blood* has been ever accounted a more terrible sight and a more fatal omen than the other preternatural rains already mentioned. In the vulgar mind it could be nothing else but the forerunner of horrible wars and bloody battles, and yet the phenomenon, despite its sanguinary colour, is no more prophetic of ensuing evil than a common shower of rain. A very memorable instance took place at the Hague in the year 1670. Swammerdam, who relates it, tells us that one morning the whole town was in an uproar on finding their lakes and ditches full of blood, as they thought; and having been certainly full of water the night before, they agreed it must have rained blood in the night; but a certain physician went down to one of the canals, and taking home a quantity of the blood-coloured water, he examined it by the microscope, and found that the water was water still, and had not at all changed its colour; but that it was full of prodigious swarms of small red animals, all alive and very nimble in their motions, whose colour and extraordinary number gave a sanguinary tinge to the whole body of the water they lived in. The discovery of the real cause did not, however persuade the Hollanders to part with the miracle. They prudently concluded that the sudden appearance of such a number of animals was as great a prodigy as the raining of blood would have been, and many of them no doubt retained their conviction that this portent foretold the scene of war and destruction which Louis XIV. afterwards brought into their country.

The animals which thus colour the water of lakes and ponds are the *Pulices arborescentes* of Swammerdam, a species of water-flea with branched horns. These creatures are of a reddish-yellow or flame colour; they live about the sides of ditches, under weeds and among the mud, and are therefore generally concealed from sight except in June, when they leave their recesses to float loose about the water, to which they impart its alarming tinge. They make their appearance in one part or other of almost all standing waters at this time of the year; and it is always at this season that the bloody waters have terrified the ignorant. Upon the whole, all the supposed marvellous rains have been owing to substances naturally produced on the earth, and either have never been in the air at all, or have only been carried thither by accident.

CHAPTER XIII.

THE RAINBOW.

The Rainbow a Symbol of Divine Favour—Iris—Production of the Rainbow—Effective Rays—Visual Axis—Secondary Rainbow—Unusual Rainbows—Decription of one by Dr. Halley—Lunar Rainbows—Marine Rainbows—Sunbows in the Spray of Cataracts.

THE rainbow, that glorious bridge which so beautifully spans its sevenfold arch across the dark background of the clouds,

> When the winds have ceased to be loud,
> And the rivers of rain to run,

has been at all times joyfully welcomed as a symbol of divine favour. While the forked lightning awakened fear and trembling, and the northern light, the supposed forerunner of bloody wars, filled the heart with imaginary terrors, the rainbow appeared as the friendly herald of peace and serenity after the raging storm.

The Bible tells us that Jehovah set his bow in the cloud as a token of a covenant between him and the earth; and Iris, the goddess of the rainbow, is one of the most graceful figures of Grecian mythology. The gigantic Thaumas, 'the wonderful,' whose name expressed the various grand phenomena of the ocean, and the sea-nymph Electra, 'glittering effulgence,' were her parents. As the rainbow is the symbol of the union between heaven and earth, Iris or Thaumantia was the fit messenger of the gods. Waving her golden pinions, she flew down to earth with the behests of Olympus, swift as the snow sweeping along in the blast or as hail driven by the north wind.

Among the old Teutonic nations, the rainbow was the

RAINBOW.

radiant bridge over which gods and heroes passed on their way to the festive halls of Walhalla; and even among the wild sons of the Polar regions we find poetic fancies awakened by its appearance, for the gloomy Samojede,[1] who places the residence of Num—his chief divinity—in the clouds, calls the rainbow the hem of his garment.

No wonder that a phenomenon capable of warming even the dull imagination of a savage, should have inspired Campbell with one of the happiest effusions of his muse.

Triumphal arch, that fill'st the sky
  When storms prepare to part,
I ask not proud Philosophy
  To teach me what thou art.

Still seem as to my childhood's sight
  A midway station given,
For happy spirits to alight
  Betwixt the earth and heaven.

Can all that optics teach unfold
  Thy form to please me so,
As when I dreamt of gems of gold
  Hid in thy radiant bow.

When Science from Creation's face
  Enchantment's veil withdraws,
What lovely visions yield their place
  To cold material laws. . . .

But though the poet thus eloquently laments the disenchanting influence of science on the creations of fancy, and Keats pours forth a similar complaint, that 'the mystical bow in the heavens is now told of in the dull catalogue of common things,' science opens, in fact, a new series of wonders by the revelation of those marvellous laws of light, which, by their play within myriads of drops of water, occasion so charming an effect.

The rainbow loses, indeed, nothing of its beauty when we are told that it is produced by the decomposition of the white light of the sun when it passes into the drops, and by its reflection from their inside face. Its appearance and its extent depend on the position of the observer, and on the height of the sun above the horizon; hence, only some of the rays refracted by the raindrops, and reflected in their concavity to the eye of the spectator, are adapted to produce the phenomenon. Those which do so are called *effective* rays, and form a circular band, in which the colours of the decomposed rays are presented in regular order, as each colour possesses a different degree of refrangibility, and strikes the eye at a different angle. The effective rays which produce the rainbow have a common axis, called the *visual axis.*

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[1] See 'The Polar World,' chap. xiv.

As this right line is parallel to the rays of the sun, it follows that when this axis is on the horizon the visual axis is itself horizontal, and the rainbow appears as a semicircle. If the sun rises, the visual axis sinks, and with it the rainbow. Lastly, when the sun is at the height of 42·2°, the arc disappears entirely below the horizon. And as it can only be seen when the back of the observer is turned to the sun, it follows that it must appear in the morning in the western sky, at noon in the northern, and then only in those latitudes where the sun at the time is below the height of 42·2°; in the evening in the east, and never in the south.

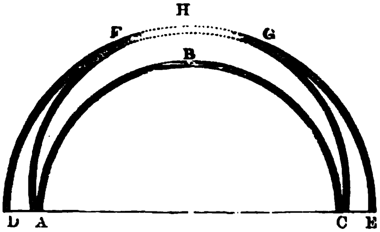
The secondary or external bow is formed by rays which have undergone two reflections, and shows its paler colours in an inverted order. It only ceases to be visible when the sun is 54° above the horizon, and may thus still be seen when the interior rainbow is sunk below it.

Although the raindrops are constantly in motion, and each of them, as it falls within the limits of the effective rays, only contributes for a moment to the phenomenon of the rainbow, yet its place is so rapidly filled up by succeeding raindrops, that the whole phenomenon has the appearance of an uninterrupted uniformity and duration. The effect is the same, though the individual agents are perpetually changing. Proceeding from a dark cloud, each drop flares but for a single instant in gorgeous colour—to disappear for ever after in darkness—a fine picture or emblem of the transitory condition of human life.

To crown the wonders of the rainbow, I may add that no two observers see the same one; just as several persons, on viewing the moon reflected in the water, are affected by different lines of rays.

Many unusual rainbows have been observed and described.

On August 10, 1665, a faint rainbow was seen at Chartres, crossing the primary rainbow at its vertex; it was formed by reflection from the river. On August 6, 1698, Dr. Hàlley, when walking on the walls of Chester, observed a remarkable rainbow, shown in the annexed figure, where ABC is the primary bow, DHE the secondary one, and AFHGC the new bow, intersecting the latter and dividing it nearly into three parts. Where the two arches FHG and FG coincided, the secondary iris for a great space lost its colours, and appeared like a white arch at the top. The new bow AHC had its colours in the same order as the primary one ABC, and consequently the reverse of the secondary bow, and on this account the two opposite spectra at G and F counteracted each other and produced whiteness. The sun at this time shone on the river Dee, and Dr. Halley found that the bow AHC was only that part of the circle of the primary bow that would have been under the castle, bent upwards by reflection from the river.



HALLEY'S RAINBOW.

A third rainbow seen between the two common ones, and not concentric with them, is described in 'Rozier's Journal,' and is doubtless the same phenomenon as that observed by Dr. Halley. Red rainbows, distorted rainbows, and inverted rainbows on the grass, have been seen. The latter are formed by the drops of rain suspended on the spiders' webs in the fields.

The moon sometimes produces rainbows like the sun, but they are very pale. In the writings of Amerigo Vespucci we find it mentioned that he saw the iris at night several times; and to this assertion, which may be true or not, as veracity was not among his virtues, he adds the following ridiculous remarks, which give us at least an idea of the meteorological opinions of his day. Attributing the red of the arch to fire, the green to the earth, the yellow to the air, and the blue to the waters, he terminates by saying that 'this sign will cease to appear when the elements are used up, forty years before the end of the world.'

When the sea is very stormy, and the crests of the waves are perpetually dissolving in spray, the rays of the sun give rise to the phenomenon of the marine rainbows, often twenty or thirty at a time, which almost always, however, show only two colours—yellow towards the sun, and pale green on the opposite side. 'It was on the fifth day of our voyage,' says Dr. Wagner, 'at the entrance of the Caribbean Sea, when a change took place in the aspect of the sky. The mighty cumulo-stratus which generally towards noon predominated among the cloud-forms, now passed into a one-coloured grey nimbus. At three o'clock in the afternoon, an abundant

CATARACT WITH RAINBOW AT FOOT.

precipitation of rain took place. The sun stood near to the zenith in an oblique direction from the spot where, over the surface of the sea, the rain, falling in thick drops, filled the air with vapours. While the grey nimbus was dispersing under the beams of the sun, a magnificent rainbow was formed, not in the clouds, but upon the surface of the sea. While the undulatory motion of the waves was moderate, this marine rainbow advanced towards the ship, expanding into a constantly widening arc. The intensity of the colours varied accordingly as the sun shone freely or cast a fainter light through a misty veil. This singular meteorological play repeated itself several times, but with less beautiful colours.'

Not only high in the clouds does Iris span her many-coloured arch, she also mirrors herself in the misty vapours of the waterfall or the fountain. When the glistening sunbow combines with the roar of the cataract, it forms one of the most charming scenes in the wide realms of Nature. Whoever, on a bright sunny morning, has seen its play of colours in the curling mists of the Staubbach or the Rhinefall will surely never forget the beautiful spectacle as long as his memory lasts.

'The majestic valley below the Falls of Niagara,' says Dickens,[1] 'so seen through the vast cloud of spray, was made of rainbow. The high banks, the riven rocks, the forests, the bridge, the buildings, the air, the sky, were all made of rainbow. Nothing in Turner's finest water-colour drawings, done in his greatest day, is so ethereal, so imaginative, so gorgeous in colour, as what I then beheld. I seemed to be lifted from the earth, and to be looking into heaven.'

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[1] 'The Life of Charles Dickens,' by John Forster. Tauchnitz Edition, vol. vi. p. 127.

CHAPTER XIV.

THE MIRAGE—THE SPECTRE OF THE BROCKEN—HALOS—MOCK SUNS AND MOONS.

Deceptive Effects of Refraction—Unusual Refractions—Looming—Interesting Instances observed at Hastings, Dover, and Malta—The Fata Morgana—Inverted Images—Carl Vernet—Scoresby—Lateral Refraction—The Serab—The Spectre of the Brocken—First Account of it by Hane—Curious Case observed near Radnor—Luminous Rings or Aureolæ observed by Ulloa, La Condamine, Tyndall, Coaz, by Aeronauts—Remarkable Phenomena of Diffraction in Mountainous Countries described in a Letter from Professor Necker to Sir David Brewster—Its Cause Experimentally Proved—Halos or Coronæ—Lesser and Greater Halos—The Production of Halos Experimentally Illustrated—Mock Suns and Moons—Diverging and Converging Beams of the Sun.

WHEN rays of light fall obliquely upon a medium varying in density, it is well known that they are refracted, or bent back, from their original rectilinear direction. But the different aerial strata are constantly varying in density, and consequently in refractive power; so that, except in a vertical line, where no refraction takes place, the rays of light proceeding from a distant object must necessarily describe a curve. Hence, neither a star nor planet beyond our atmosphere, nor any remote body actually within it, is seen in its right place. It is owing to an effect of refraction that the western sun still seems to shine upon us after his orb has really set, and that before the moon has actually risen, her image makes its appearance in the sky. Our eyes, in fact, are constantly deceiving us; but, except in astronomical and trigonometrical observations, where the greatest accuracy is necessary, the refraction of the atmosphere does not occasion any inconvenience, and generally remains unnoticed. Sometimes, however, a great local heat or cold, by producing considerable changes in the density and refractive power of the air, gives rise to optical phenomena of a very interesting kind. Such phenomena have received the name of *unusual refraction* or *mirage*, and they are sometimes of so extraordinary a nature as to resemble more the effects of magic than the results of natural causes.

The commonest cases of mirage, which have long been observed, and known by the name of looming, are when distant objects—villages, coasts, ships—actually situated below the horizon are raised above it, and become visible either to the naked eye, or through a telescope; a deception which often takes place without the spectator being aware that it is one. Thus Zimmermann relates that from the strand of Zoppot, a sea-bathing place near Danzig, one frequently sees the aerial picture of the peninsula of Hela, with its lighthouse and its small village. But Hela is twenty-five geographical miles from Zoppot, and consequently below the horizon of a strand not six feet above the level of the sea. The phenomenon only shows itself in the middle of the day, in clear weather—never in the morning or evening; it suddenly appears and vanishes, yet the people, knowing Hela to be situated in that direction, never think of it as an optical delusion.

One of the most remarkable cases of an unusual extension of range of vision due to looming occurred on July 26, 1798, at Hastings, at 5 P.M., when Mr. Latham saw the French coast, which is about forty or fifty miles distant, as distinctly as through the best glasses. The sailors and fishermen could not at first be persuaded of the reality of the appearance, but as the cliffs gradually appeared more elevated, they were so convinced that they pointed out to Mr. Latham the different places they had been accustomed to visit, such as the bay, the windmill at Boulogne, and other places on the coast of Picardy. All these places appeared to them as if they were sailing at a small distance into the harbour. From the eastern cliff or hill, Mr. Latham saw at once Dungeness, Dover cliffs, and the French coast, all the way from Calais, Boulogne, on to St. Valéry, and, as some of the fishermen affirmed, as far as Dieppe. The day was extremely hot, without a breath of wind, and objects at some distance appeared greatly magnified.

Another truly magical case of looming was observed at Dover on May 26, 1868. The cupola of the cathedral and Napoleon's column at Boulogne were plainly seen from Crescent Walk by the naked eye. Through an eyeglass of ordinary power, the entrance of the harbour, its lighthouse, its ships and the surrounding buildings, were distinctly visible, as well as towards the west the chief outlines of the coast, the lighthouse of Cape Grisnez, and a great number of villages and farms, with their windows illuminated by the setting sun. While observing all these objects, a locomotive was seen to leave Boulogne, and to drive along with its clouds of steam in the direction of Calais. Soon after sunset the wonderful illusion vanished, most probably not to reappear until after the lapse of many years.

On March 20, at noon, the report spread at Malta that a new island had risen from the sea, in the channel, at a distance of about four or six leagues, and several ships sailed out of the harbour to take possession of it. From the terrace of the observatory, the astronomer Dangos[1] saw through a telescope the white summit of this supposed island, which, from its lying exactly in the direction of Mount Etna, he soon found out to be merely its refracted image. After about half an hour the island seemed gradually to recede, and the real Etna, with the coast of Sicily, which meanwhile had been depressed under the level of the sea, again made its appearance. From the islands of Comino and Gozzo the new island was likewise seen. On April 17 in the following year, Dangos again saw the phenomenon, and distinctly observed the gradual formation and disappearance of the aerial island.

On the banks of the Orinoko, Humboldt and Bonpland found at noon the temperature of the sand to be as high as 128° in the sun, while that of the air twenty feet above the ground was only 104°. A range of hills ten English miles distant seemed to be floating in the air, and some palm-trees, which stood singly in the Llanos, to be without a trunk. In the Savannas, the light air currents undulating over the heated soil, produced such differences of temperature and refraction that part of a herd of wild oxen only about a mile distant seemed to hover in the atmosphere, while others retained their natural position on the ground. In the Bay of Caraccas, Humboldt frequently noticed that in consequence of the great difference of temperature and density of the air above the land and the water, the rocky islets which guard its entrance appeared after noon to be more elevated than at other times. It was interesting to follow by day the changeable phenomenon, and to see, as night approached, the rocks, which had apparently been raised into the air, sink down again, as it were, upon their bases.

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[1] 'Mémoires de l'Institut étrangers,' tom. i. p. 462.

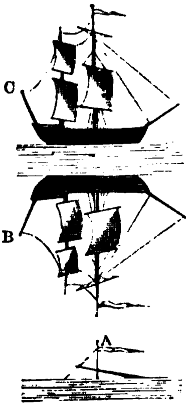
Since time immemorial the remarkable phenomena of mirage which occur from time to time in the Straits of Messina, and particularly at Reggio, on the coast of Calabria, have astonished the vulgar and perplexed philosophers. They are generally known under the name of the Fata Morgana, or castles of the fairy Morgana, a potent enchantress, to whom superstition ascribed their magical apparition. Of this phenomenon we have most exaggerated accounts. We are told that a spectator, standing on an eminence of the city of Reggio, with his back to the sun and his face to the sea, and when the rising sun shines from that point at which its rays fall from an angle of about 45° on the sea of Reggio, sees upon the water numberless series of pilasters, arches, castles well delineated, regular columns, lofty towers, superb palaces, with balconies and windows, villages and trees, plains with herds and flocks, and *armies of men on foot and on horseback*, all passing rapidly in succession on the surface of the sea. In particular states of the atmosphere, all these wonderful phantasms, which, if really observable, might be supposed to open a glimpse into fairyland, are seen in the air, though less vividly; and when the atmosphere is hazy, they appear on the surface of the sea vividly coloured, or fringed with all the prismatic hues. Deducting from the Fata Morgana the embellishments which have been added to reality by an Italian fancy, it is no doubt a remarkable case of looming, through which the town of Messina and its environs become visible for a time to the people on the opposite coast.

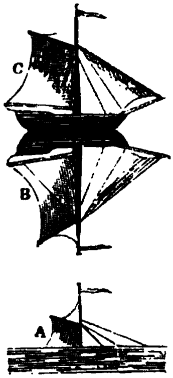
In other cases of mirage, which are extremely common across extensive sheets of calm water, distant objects seem inverted above their true position. Usually two images are seen, namely, an erect image in the true, or what appears to be the true, position, and an inverted image above it. Sometimes, however, the inverted image is visible when the erect image is hidden by the convexity of the intervening water.

This phenomenon is explained by a very rapid increase of temperature upwards in a stratum of air overhead. The inverted images are formed by rays incident from below upon this stratum at such an obliquity that they cannot get through, but are compelled to descend again, and thus undergo a kind of reflection.

Sometimes multiple images are seen above the true position of the object. In this case there are either several strata rapidly increasing in temperature, and each of them fulfilling the image of a mirror, or a single such stratum of irregular shape, yielding reflections in different places.

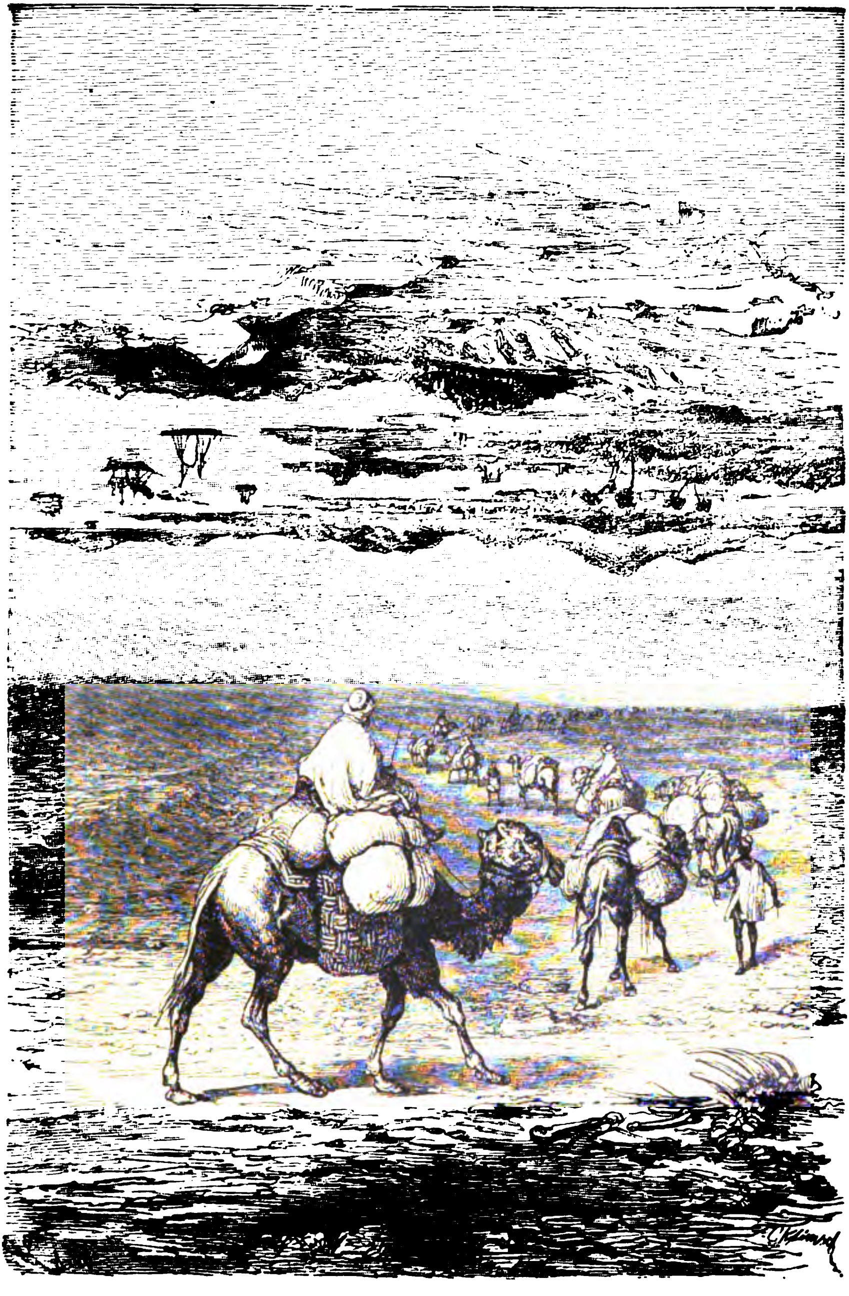
During a voyage in Italy, which he had undertaken for the purpose of studying the various phenomena of clouds and effects of light, the celebrated painter, Carl Vernet, once saw high above the horizon the image of an inverted city, with its church steeples and houses. He lost no time in taking a sketch of the phenomenon; and, anxious to ascertain the cause, walked on in the direction where it had made its appearance. At a distance of about seven leagues, he found, to his astonishment, the town the image of which he had seen in the clouds.





MULTIPLIED AND INVERTED IMAGES.

Dr. Vince observed at Ramsgate a ship, A, whose topmasts only appeared above the horizon, but he at the same time observed, in the field of the telescope through which he was looking, two images, B, C, of the complete ship in the air, both directly above the ship, the uppermost of the two being erect and the other inverted. In another case, the sea was dis-



MIRAGE.

tinctly seen between the images B and C. As the ship A came above the horizon, the image C gradually disappeared, and during this time the image B descended. The two images were visible when the whole ship was beneath the horizon.

The phenomenon of inverted and multiplied images of distant objects was noticed several times by Scoresby when navigating the Greenland Seas.

On June 28, 1820, he saw from the masthead eighteen sail of ships at the distance of about twelve miles. One of them was drawn out or lengthened, in a vertical direction; another was contracted in the same direction; one had an inverted image immediately above it, and the other two had two distinct inverted images above them, accompanied with two images of the strata of ice. In 1822 he recognised his father's ship, the 'Fame,' by its inverted image in the air, although the ship itself was below the horizon. Through a Dollond's telescope every sail could be distinctly distinguished, though it was afterwards found that the ship was seventeen miles beyond the horizon, and its distance thirty miles.

In all these instances, the image was directly above the object; but on September 17, 1818, Messrs. Jurine and Soret observed an extraordinary case of lateral refraction. A bark about 4,000 toises distant was seen approaching Geneva by the left bank of the lake; and, at the same moment, there was seen above the water an image of the sails, which, in place of following the direction of the bark, receded from it, and seemed to approach Geneva from the right bank of the lake; the image sailing from east to west, while the bark was sailing from north to south. The image was of the same size as the object when it first receded from the bark, but it grew less and less as it receded, and was only one-half that of the bark when the phenomenon ceased.

The vertical magnification of real objects sometimes produces an appearance of architectural columns, obelisks, and spires. A most remarkable delusion of this kind was observed by Scoresby while sailing through the open ice far from land. Suddenly an immense amphitheatre, enclosed by high walls of basaltic ice, so like natural rock as to deceive one of his most experienced officers, rose around the ship.

Single ice-blocks expanded into architectural figures of an extraordinary height, and sometimes the distant, deeply-indented ice border looked like a number of towers or minarets, or like a dense forest of naked trees. Scarcely had an object acquired a distinct form when it began to dissolve into another.

Similar appearances are not seldom seen on land; small bushes, for instance, being often expanded into tall trees.

But the phenomenon of mirage is never more striking and delusive than when it creates a false appearance of water in a place actually occupied by hot and dry ground. When the sun rises over the Sahara, all distant objects appear sharp and distinct; but as soon as the ground becomes heated, and communicates its high temperature to the lower strata of the atmosphere, a kind of tremulous agitation arises in the air. The sun, which gives life to the organic world, seems, by the varying refraction of its rays, to communicate it to inanimate nature, to move the land from its place, and to impart the undulation of the sea to the arid sands. If, at the same time, the weather is calm, and no wind disperses the heated atmospherical strata, the mirage appears with all its magical illusions, and the waterless desert is transformed into a lake, which reflects the inverted image of all the objects that rise above its level.

In the Sanscrit language this wonderful deception of vision is frequently called 'the longing of the thirsty antelope;' and the 'Serab' (mysterious water) or 'Bacher el Afrid' (the sea of the devil) is frequently alluded to in Oriental poetry, which derived a rich source of inspiration from the natural phenomena of the desert. 'The works of the unbelievers,' says the Koran, 'are like the Serab; the thirsty traveller mistakes them for water, until he approaches and finds that it is nought.'

Professor Everett[1] explains this kind of mirage by a considerable increase of temperature downwards within a few inches of the ground. This will produce an upward bending of rays and a reflection, as in the above-mentioned cases of inversion; but the seeming mirror is now below the observer's eye instead of above it. The flickering movements of the reflected images thus seen, due to currents of hotter and colder air, greatly resemble the appearances produced by the rippling of waves on a lake; but probably the most irresistible feature in the illusion is the gleam of the reflected sky. The sky itself and its reflection in water so far exceed in brightness all other objects in an ordinary landscape, that when this gleam is seen in a place where the sky cannot be, the observer feels irresistibly compelled to ascribe it to water.

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[1] 'On the Optics of Mirage,' 'London, Edinburgh, and Dublin Philosophical Magazine,' March 1873.

During the French expedition to Egypt under Bonaparte, the illusion of the mirage was often a source of grievous disappointment to the army. When after a long march through the desert the deceptive horizon showed them the blue mirror of a lake in the midst of the arid sands, they hailed it with exclamations of delight, and hastened towards the imaginary shore; but, as they approached, it still receded before them, as if in mockery of their vain efforts to attain it.

On high mountains the mists arising from the valleys sometimes show the spectator his own reflected image on a gigantic scale. This striking phenomenon, which, from having been first noticed in the Hartz Mountains, is generally known under the name of the 'Spectre of the Brocken,' has given rise to the legend of a tutelar demon supposed to stalk about among the solitary mountain ranges in the shape of a wild man of huge stature, crowned and girdled with oak leaves, and carrying a pine-tree torn up by the roots. This woodland goblin has even found his place on many of the coins and medals struck out of the silver of the Hartz; and the miners and foresters of that romantic region are still as convinced of his existence as their fathers, who fancied they saw him stride from glen to glen, while in reality it was their own magnified image that deceived them.

The credit of having first pointed out the true secret of the apparition is due to the traveller Haue, who witnessed it on May 23, 1797, after no less than thirty fruitless ascents to the summit of the Brocken. Soon after sunrise, the weather being fine, and the wind driving transparent vapours to the west, he saw in this direction a human figure of a monstrous size. A violent gust of wind having almost carried away his hat, he raised his hand to secure it, and the nebulous giant did the same. He made a stooping movement, and the spectre stooped; in short, all his gestures were repeated by his own magnified and shadowy image.

Attention having once been directed to the subject, the 'Spectre of the Brocken' has, of course, been found to make his appearance in many other parts of the world, though rarely in so distinct and engaging a form as in the following instance:—

SPECTRE OF THE BROCKEN.

On August 21, 1851, about two o'clock P.M., a young lady had ascended to the top of the Mynydd, a steep hill about 500 feet above the valley of New Radnor. The sun was bright and hot, and, having picked some flowers on the top of the hill, Miss E. descended a little way to a spot from which she could see the road and the carriage with the friends whom she had left. After waving her handkerchief, which she held in her hand, to her friends, she suddenly perceived, upon turning round, a figure standing a few yards from her upon a wet spot, from which a little thin mist was rising. The figure stood exactly facing her, and wavered a little, and she did not discover it to be her own image till she observed that, like herself, it held a handkerchief and a bunch of flowers in its hand. The dress and flowers were precisely similar to her own, and the colours so vivid that she could even see her face. The effect was the same as if she was before a looking-glass. When she moved her hand, the figure did the same. The two ladies in the carriage saw the image of Miss E., and asked her, when she joined them, what companion it was which was with her on the hill.

There can be no doubt that the figure was a reflection of Miss E. from the thin mist rising from the damp ground. There was no mist but above the wet spot; and it may be proved by experiment that when the particles of vapour are sufficiently small, they reflect light as distinctly as a surface of glass.

Sometimes the reflected image appears encircled with luminous rings, a phenomenon first described by the Spaniard Ulloa, who relates that, as he stood at break of day with six companions on the summit of Pambamarca, in Peru, each of them, on looking towards the east, saw his shadow in the centre of three rainbows, surrounded by a fourth circle of one colour. All these rainbows, or luminous segments of circles, were perpendicular to the line of the horizon; they moved with the motion of the person, whose image they surrounded like a glory. At the commencement of the phenomenon their form was oval, but towards the end of it they were perfectly circular.

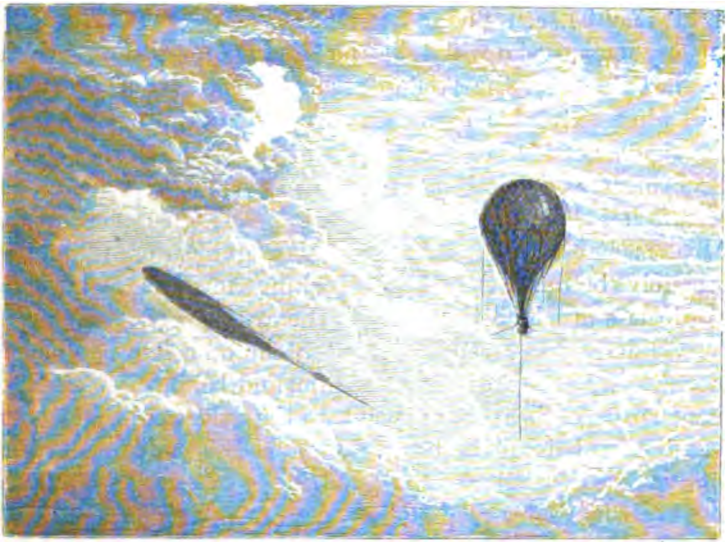
During their travels in the Cordillera, La Condamine and Bouguer witnessed the same beautiful phenomenon. 'What surprised us most,' says the latter, 'was to find the head of the figure surrounded by an aureola, formed of three or four concentric circles of very vivid tints, similar to those of the rainbow, the red being outside.'

No doubt more than one Alpine wanderer has been gratified with the sight of his reflected image crowned with a glory. 'Proceeding along the mountain to the Furca,' says Professor Tyndall ('Glaciers of the Alps'), 'we found the valley on the further side of the pass filled with fog, which rose like a wall high above the region of actual shadow. Once, on turning a corner, an exclamation of surprise burst simultaneously from my companion and myself. Before each of us, and against the wall of fog, stood a spectral image of a man of colossal dimensions, dark as a whole, but bounded by a coloured outline. We stretched forth our arms; the spectres did the same. We raised our alpenstocks; the spectres also flourished their batons. All our actions were imitated by these fringed and gigantic shadows. We had, in fact, the *Spirit of the Brocken* before us in perfection.'

Herr Coaz, of Coire, the first ascender of the Bernina Peak, had reached with great difficulty the summit of Piz Curver (9,158 feet high), in the Canton of the Grisons, when a wild gorge at the foot of the mountain attracted his attention, for one lavine after another was thundering down the precipitous rockwalls into the depths of the valley, where often several of them combined into a broad stream of silver. 'So full of life, in such uninterrupted succession, this august spectacle had never before appeared to me in all my numerous Alpine excursions. My eye was still following one of the last lavines, which were gradually becoming less frequent, when I saw a slight fog forming over it. From the rocks also mists were streaming, slowly creeping towards each other, and ultimately meeting in a grey and waving nebulous lake, which concealed the depth of the valley. Nourished from invisible sources, this lake rose perpetually higher, and finally ascended as a dark foggy veil, in which, at first weak and dissolving, but again and more vividly returning, the colours of the rainbow appeared. At length they joined into a brilliant circle, around which another one less brilliantly tinted formed itself, and in its turn was soon after encompassed by a still paler ring. The innermost circle had a diameter of about three feet, and was about thirty or forty feet distant. Delighted with the sight, I sprang up, but as suddenly remained fixed to the spot, for in the centre of the rainbow a dark figure started up with equal haste, and then stood as motionless as myself. I waved my hat, I made deep bows, and the spectre showed equal marks of joy and politeness. The apparition lasted a few minutes, and then vanished along with the rainbows in the grey fog, which, wafted away by a slight wind, melted in the air. It was four o'clock in the afternoon.'

The aeronauts, who enjoy such unusual opportunities of seeing cloud-land under every possible combination of sunshine and mist, frequently observe the phenomenon in question.

'At a moment,' says M. Flammarion,[1] 'when we least expected to see anything remarkable, we found ourselves near to the singularly undulated surface of the cloud-tops, and suddenly, at less than 100 feet from us perhaps, and opposite to the sun, which had just revealed itself, we see the lower portions of a balloon about the same size as our own, and suspended to it a car, containing two travellers, whose forms are so familiar that we recognise them without any difficulty. The minutest details are apparent—even the thinnest ropes and the cords and instruments suspended to them. I make a motion with the right arm; my spectre moves his left. Godard flourishes the national flag, and the



BALLOON REFLECTION ON CLOUDS.

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[1] Ascent from Paris to Beaugency, April 15, 1868. Glaisher's 'Travels in the Air,' p. 220.

shadow of a flag is moved by the spectral hand in the air. All around the image of the car we see concentric circles of various colours.'

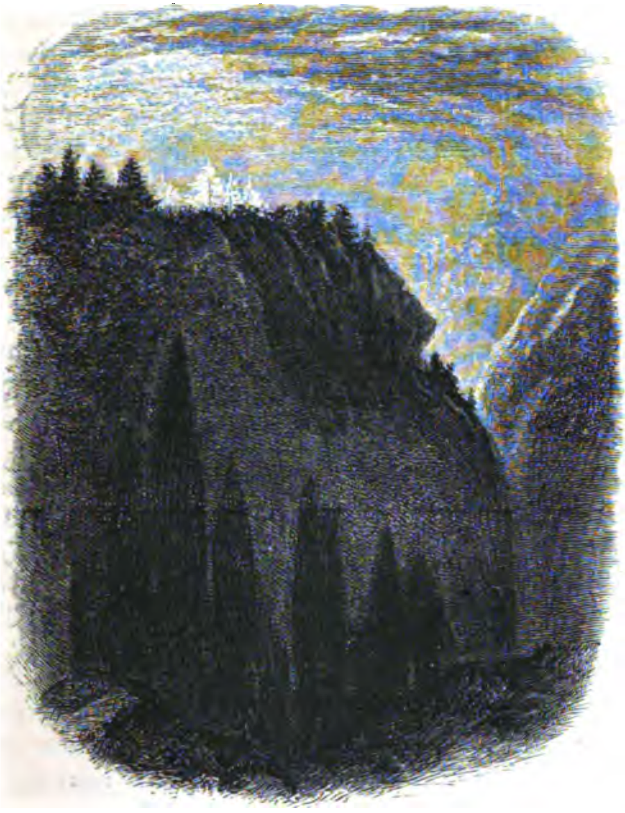
M. Flammarion adds that this was the first time this interesting spectacle had ever been witnessed in a balloon; but Mr. Glaisher tells us that he always saw the image of the balloon, the car, and its inmates surrounded with several luminous concentric circles on the clouds on passing above them in bright sunshine.

Indeed, without ascending into the air, the same phenomenon, which in every case is due to the diffraction of light, may be seen under far more common circumstances; for any person who will take the trouble of walking early in the morning over the ground covered with dew, can scarcely fail, when fixing his eyes on a carpet of verdure, to observe the shadow of his head surrounded by sacred glory.

Professor Tyndall mentions a remarkable phenomenon of diffraction, which, though by no means uncommon in the Alps, is hardly ever seen by either guides or travellers, probably because they avoid looking towards a sky the brightness of which is painful to the eyes.

While he was ascending Mont Blanc on a fine September morning, a brow rose in front of him, and behind it was a lustrous space of heaven, adjacent to the sun, which, however, was hidden behind the brow. Against this space the twigs and weeds upon the summit of the brow shone as if they were self-luminous, while some bits of thistle-down, floating in the air, appeared, when they crossed this portion of the heaven, like fragments of the sun himself. This beautiful phenomenon was first brought into notice by Professor Necker, in a highly interesting letter to Sir David Brewster.

'I now come to the point,' writes the Genevese savant, 'which you particularly wished me to describe to you—I mean the luminous appearance of trees, shrubs, and birds, when seen from the foot of a mountain a little before sunrise. The wish I had to see again the phenomenon before attempting to describe it, made me detain the letter a few days, till I had a fine day to go to see it at the Mont Salève; so yesterday I went there and studied the fact. You must conceive the observer placed at the foot of a hill, interposed between him and the place where the sun is rising, and thus entirely in the shade. The upper margin of the mountain is covered with wood or detached trees and shrubs, which are projected as dark objects on a very bright and clear sky, except at the very place where the sun is just going to rise, for there all the trees and shrubs bordering the margin are entirely—branches, leaves, stem, and all—of a pure and brilliant white, appearing extremely bright and luminous, although projected on a most bright and luminous sky, as that part of it which surrounds the sun always is. All the minutest details—leaves, twigs, &c.—are most delicately preserved, and you would fancy you saw these trees and forests made of the purest silver with all the skill of the most expert



SUNRISE. SUN ILLUMINATING TREES FROM BEHIND.

workman. The swallows and other birds flying in those particular spots appear like sparks of the most brilliant white.'

Neither the hour of the day nor the angle which the object makes with the observer appears to have any effect, for Professor Necker saw the phenomenon both at a very early hour in the morning and in the afternoon. At one time the angle of elevation of the lighted white shrubs above the horizon of the spectator was about 20°, while at another place it was only 15°. But the extent of the field of illumination is variable, according to the distance at which the spectator is placed from it. When the object behind which the sun is just going to rise, or has just been setting, is very near, no such effect takes place. At the moderate distance of five or six hundred feet, and at a height above the level of the spectator of about two hundred feet, only small shrubs are illuminated white, and the horizontal extent of this effect is also comparatively small; but when the phenomenon is witnessed at a greater distance and at a greater height, considerable tracts of forests and large trees are illuminated white throughout their whole length.

'Nothing can be finer,' continues the Professor, 'than these silver-looking, spruce forests. At the same time, though at a distance of more than a thousand mètres, a vast number of large swallows, or swifts (*Cypselus alpinus*), which inhabit these high rocks, were seen as small brilliant stars or sparks moving rapidly in the air. From these facts it appears to me obvious that the extent of the illuminated spots varies in a direct ratio of their distance, but, at the same time, that there must be a constant angular space, corresponding probably to the zone, a few minutes of a degree wide around the sun's disk, which is a limit to the occurrence of the appearance. This would explain how the real extent which it occupies on the earth's surface varies with the relative distance of the spot from the eye of the observer, and accounts also for the phenomenon being never seen in the low country, where I have often looked for it in vain. Now that you are acquainted with the circumstances of the fact, I have no doubt you will easily observe it in some part or other of your Scotch hills. It may be some long heather or furze will play the part of our Alpine forests, and I would advise you to try and place a bee-hive in the required position, and it would perfectly represent our swallows, sparks, and stars.'

The following experiments clearly prove that this beautiful phenomenon is due to the diffraction of light, or the bending of the waves of ether round the edge of an object, whereby they are made to clash on the other side. The celebrated Thomas Young permitted a beam of sunlight to enter a dark room through an aperture made with a fine needle, and, placing in the path of the beam a bit of card one-thirtieth of an inch wide, he found the shadow of this card, or rather the line on which its shadow might be supposed to fall, always bright. This effect he proved to be due to the bending of the waves of ether round the two edges of the card and their coincidence at the other side. It has also been shown by M. Poisson that the centre of the shadow of a small circular opaque disk, which stands in the way of a beam diverging from a point, is exactly as much illuminated as if the disk were absent.

These experiments show how possible it is for the solar rays, in grazing a distant tree, so to bend round it as to produce upon the retina, where shadow might be expected, the impression of a tree of light.[1]

An analogous phenomenon has also been observed by 'travellers in the air.' On June 10, 1867, M. Flammarion had ascended shortly after sunrise to a height of about 4,000 feet, when he was surprised to find that the shadow of his balloon was white. It appeared like a vast luminous patch covering several acres of ground. The surface on which it fell, whether forest or field, appeared more luminous than the rest of the country.

In a clear sky the sun and moon appear without any change of colour, and without any attendant phenomena; but when their disks are partially veiled by light fleecy clouds, they are not seldom seen encircled with one or more white or coloured rings, called halos or coronas. These rings, which also sometimes form round Sirius and Jupiter, are very common round the sun, though from the overpowering brightness of his rays they are best seen when he is observed by reflection from the surface of still water. They are due, as Fraunhofer has shown, to the diffraction of light by small globules of fog in the atmosphere, and the renowned optician has even given a method of estimating the mean diameter of these globules from the dimensions of the halos. Coronas may easily be produced by placing a lighted candle in the midst of steam, or by breathing upon a glass window in cold weather, and looking through it at a light placed some feet from it. A beautiful phenomenon of the same kind may be produced by looking at a flame through lycopodium powder strewed on glass.

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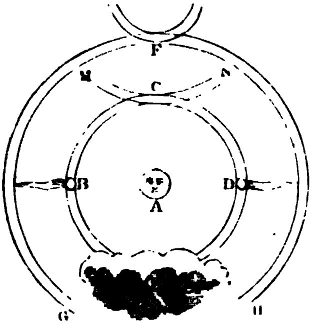
[1] Professor Tyndall thinks, however, that the strong irradiation from the glistening sides of the twigs and branches must also contribute to the same result.

Besides the common corona, the sun and moon sometimes show the more rare and far more beautiful phenomenon of larger and more complicated halos, consisting of concentric circles, circles passing through their disks, segments of circles, and mock suns and moons formed at the points where these circles intersect each other. The mock luminaries attending these halos are called parhelia when seen round the sun, and paraselenæ when seen round the moon.

The annexed figure of a paraselene, observed by Hevelius at Dantzic, on March 30, 1660, at one A.M., will serve to give a better idea of this phenomenon than a mere verbal description.

The moon A was seen surrounded by an entire whitish circle, B C D E, in which there were two mock moons, at B and D, one at each side of the moon, consisting of various colours, and shooting out very long and whitish beams by fits. At about two o'clock a larger circle surrounded the lesser, and reached to the horizon. The tops of both these circles were touched by coloured arches, like inverted rainbows. The inferior arch at C was a portion of a large circle, and the superior at F a portion of a lesser. This phenomenon lasted nearly three hours. The outward great circle vanished first; then the larger inverted



PARASELENÆ.

arch at O, and then the lesser; and, last of all, the inner circle, B C D E, disappeared. The diameter of the inner circle, and also of the superior arch, was 45°, and that of the exterior circle and inferior arch was 90°.[1]

The frequent occurrence of the larger halos in cold weather, and especially in the northern regions of the globe, first led to the supposition that they must be due to the refractive power of crystals of ice and snow floating in the air—an hypothesis which has been fully verified by the investigations of Huyghens, Mariotte, Young, Bravais, and other eminent physicists.

'The production of halos,' says Sir David Brewster,[2] 'may be illustrated experimentally by crystallising various salts upon plates of glass, and looking through the plates at the sun or a candle. When the crystals are granular and properly formed, they will produce the finest effects. A few drops of saturated solution of alum, for example, spread over a plate of glass, so as to crystallise quickly, will cover it with an imperfect crust, consisting of flat, octohedral crystals, scarcely visible to the eye. When the observer, with his eye placed close behind the smooth side of the glass plate, looks through it at a luminous body, he will perceive three fine halos at different distances, encircling the source of light. The interior halo, which is the whitest of the three, is formed by the refraction of the rays through a pair of faces in the crystals, that are least inclined to each other. The second halo, which is *blue* without and *red* within, with all the prismatic colours, is formed by a pair of more inclined faces; and the third halo, which is large and brilliantly coloured, from the increased refraction and dispersion, is formed by the most inclined faces. As each crystal of alum has three pairs of each of these included prisms, and as these refracting faces will have every possible direction to the horizon, it is easy to understand how the halos are completed and equally luminous throughout.

That a phenomenon caused by ice crystals floating in the air is not confined to winter or to the polar zone, but also shows itself within the tropics, is not to be wondered at when we consider that even under a vertical sun the upper regions of the atmosphere are intensely cold, so that the aqueous vapour of any warm air current that rapidly ascends to a considerable height is liable to congelation. Aeronauts have often left warm summer below and met with snow in the clouds above.

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[1] Sir David Brewster's 'Treatise on Optics.'

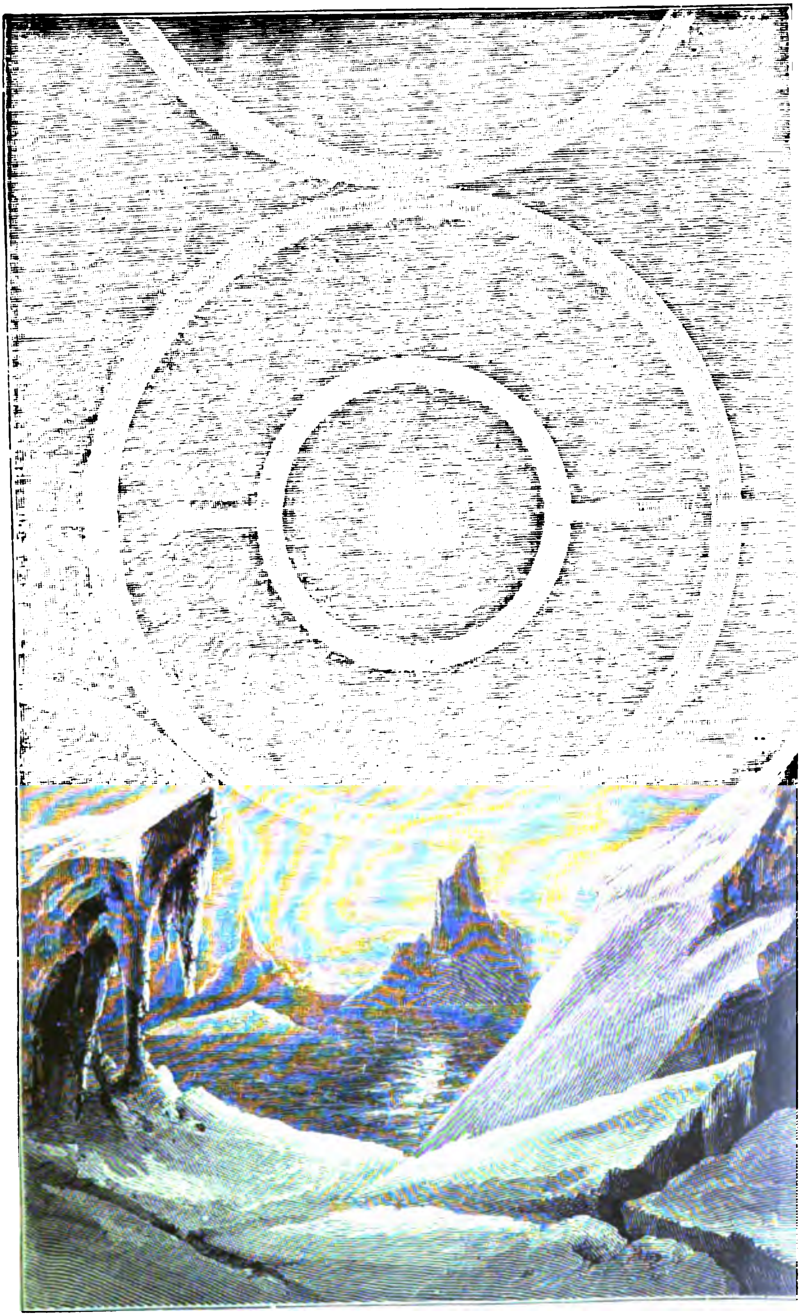
[2] 'Treatise on Optics.'

Of all the phenomena attending a great halo none is more striking than that of the mock suns and moons. These brilliant atmospherical apparitions were, of course, well known to the ancients, as they have existed at all times, and are too extraordinary to escape attention. 'Our forefathers,' says Pliny, 'have more than once seen three suns at the same time;' and Seneca remarks that though these luminous meteors are called suns, they are faint and powerless, and give no warmth.

A very remarkable instance of mock suns was seen at Rome on March 20, 1629, and is frequently mentioned in works on meteorology, under the name of the Roman phenomenon. Four of these splendid meteors with different rings were seen of a brilliancy nearly equal to that of the sun itself. On their borders they were coloured like the rainbow, and were not round, but with uneven outlines. One of them was continually in a tremulous motion, and shot out fiery beams.

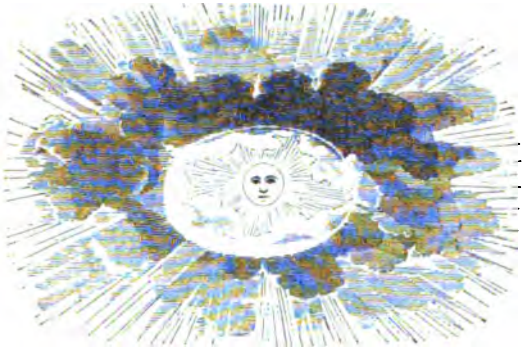
On January 26, 1661, Hevelius saw at Dantzic the sun with no less than six of its mock images—a sight which filled him with astonishment and admiration. Very different was the impression which the phenomenon of four mock suns on September 15, 1851, made upon the country-people near Geneva, who witnessed the gorgeous spectacle. Instead of admiring the wonderful optical illusion, they were struck with the utmost terror, for in their simplicity they firmly believed that the sun was multiplying himself to set the earth on fire. With fear and trembling, they expected every moment to hear the trumpets of the Last Judgment; but a few minutes showed their terror to be vain, for soon the lustrous phantasms disappeared, and the heavens remained mute.

In summer the solar beams are often seen to diverge, in



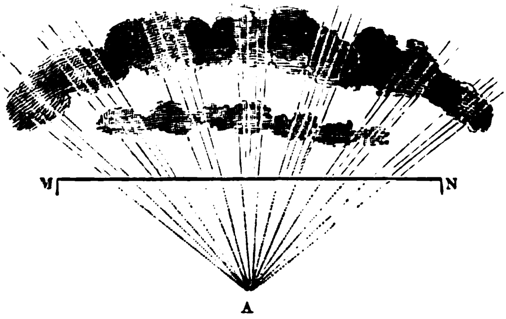
LUNAR HALO WITH MOCK MOONS.

consequence of a portion of the sun's rays, when it is near the horizon, passing through openings in the clouds by which the adjacent portions are obstructed.



DIVERGING BEAMS.

The phenomenon of converging beams is shown in the annexed woodcut, where the rays converge to a point, A, as far below the horizon, M N, as the sun is above it. This phenomenon is always seen opposite to the sun, and generally at the same time with the phenomenon of diverging beams, as if another sun diametrically opposite to the



CONVERGING BEAMS.

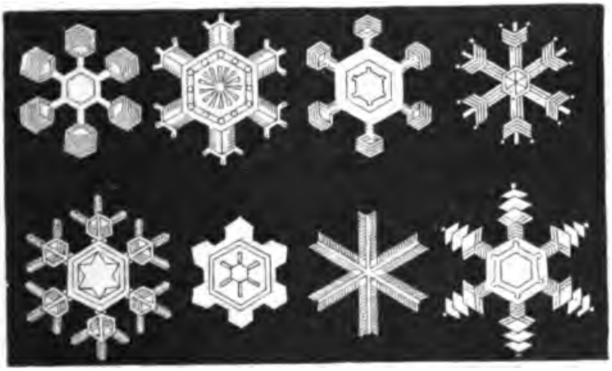
real one were below the horizon at A, and throwing out the diverging beams. In a phenomenon of this kind, which Sir David Brewster saw in 1824, the eastern portion of the horizon, where it appeared, was occupied with a black cloud, which seems to be necessary as a ground for rendering visible such feeble radiations. A few minutes after the phenomenon was first seen, the converging lines were black or very dark, an effect which seems to have arisen from the luminous beams having become broad, and of unequal intensity, so that the eye took up, as it were, the dark spaces between the beams more readily than the luminous beams themselves.

CHAPTER XV.

SNOW.

Snow Crystals—Their Construction—A Snow-fall on the Summit of Monte Rosa and on the Mer de Glace—Molecular Architecture of Ice—Snow Storms on the Kirghez Steppes—On the Alps—On the Cordillera and the United States—The Lavines—Beneficial Effects of Snow—The St. Bernard's Dogs—Snow Shoes—Limits of Snow in the Northern Hemisphere—The Snow Line—Warmth of Sun above the Snow Line—Glaciers—Their Movements—Crevices—Dangerous Falls—The Falling-in of Glaciers—The Gentroz Glacier—Inundation in the Valley of Bagnes—Icebergs—Cause of Glacier Motion—Regelation—Purity of Glacier Ice a Consequence of Pressure.

WHEN the temperature of the atmosphere falls below the freezing point of water, the minute vesicles or droplets which constitute the clouds are no longer able to maintain their liquid state, but congeal in stellate crystals.



SNOW CRYSTALS.

These minute spiculæ, in their gradual descent, form small snow-flakes, which, uniting with others, at last reach the earth. Though consisting of firm ice, their proverbial lightness is owing to the excess of their surface in comparison to the matter contained under it; as gold itself may be extended in surface till it rides like a gossamer upon the least breath of air.

On a closer examination, each perfect snow-flake is found to be as beautifully constructed as the costliest gem that sparkles in a regal tiara. It consists of six points, diverging like rays from a common centre, and uniformly inclosing angles of 60°. From these points or needles diverge on each side smaller spiculæ, which, with infallible accuracy, describe the same angles, and thus give birth to six-leaved flowerets, whose surfaces are often again clustered over with other crystals or efflorescences of still more microscopical dimensions. Thus one beautiful object engrafts itself upon another as if Nature had delighted to show the wonders of her workmanship in the narrowest space.

Though all snow-flakes are thus similarly constructed, the crystals of which they are composed branch out into an endless variety of forms, whose beautiful regularity may be investigated by collecting them on a black surface, and viewing them through a strong lens. In the Arctic regions, or wherever a calm and intensely cold atmosphere favours their crystallisation, their elegance assumes the most remarkable character.

Professor Tyndall describes a fall of snow he witnessed on the summit of Monte Rosa as a shower of frozen flowers. 'All of them were six-leaved; some of the leaves threw out lateral ribs like ferns; some were rounded, others arrowy and serrated; some were close, others reticulated, but there was no deviation from the six-leaved type. Nature seemed determined to make us some compensation for the loss of all prospect, and thus showered down upon us those lovely blossoms of the frost; and had a spirit of the mountain inquired my choice—the view or the frozen flowers—I should have hesitated before giving up that exquisite vegetation. It was wonderful to think of as well as beautiful to behold. Let us imagine the eye gifted with a microscopic power sufficient to enable it to see the molecules which composed these starry crystals; to observe the solid nucleus formed and floating in the air; to see it drawing towards it its allied atoms, and these arranging themselves as if they moved to music, and ended by rendering that music concrete. Surely such an exhibition of power, such an apparent demonstration of a resident intelligence in what we are accustomed to call "brute matter" would appear perfectly miraculous. And yet the reality would, if we could see it, transcend the fancy. If the Houses of Parliament were built up by the forces resident in their own bricks and lithologic blocks, and without the aid of hodman or mason, there would be nothing intrinsically more wonderful in the process than in the molecular architecture which delighted us upon the summit of Monte Rosa.'[1]

On another occasion, while engaged in measuring the onward movement of glaciers during the winter on the Mer-de-Glace, his admiration was excited by a similar beautiful snowfall. 'Some time afterwards the air became quite still, and the snow underwent a wonderful change. Frozen flowers, similar to those I had observed on Monte Rosa, fell in myriads. For a long time the flakes were wholly composed of these exquisite blossoms entangled together. On the surface of my woollen dress they were soft as down; the snow itself on which they fell seemed covered by a layer of down, while my coat was completely spangled with six-rayed stars. And thus prodigal Nature rained down beauty, and had done so here for ages, unseen by man. And yet some flatter themselves with the idea that this world was planned with strict reference to human use; that the lilies of the field exist simply to appeal to the sense of the beautiful in man. True, this result is secured; but it is one of a thousand all equally important in the eyes of Nature. Whence those frozen blossoms? Why for aeons wasted? While I remained at the station a layer of snow an inch thick fell upon the blanket, the whole layer being composed of these exquisite flowers. The atmosphere also was filled with them. From the clouds to the earth Nature was busy marshalling her atoms, and putting to shame, by the beauty of her structures, the comparative barbarities of art.'[2]

Not only when the condensed aqueous vapours congeal in the air under the form of snow do their particles congregate in six-rayed stars, but in water also a similar molecular architecture goes on, when it freezes into a solid mass. The largest blocks of ice which reach us from Norway are wholly built up in this way. This can be proved by sending an agent into the interior of a mass of ice, which takes down the atoms which the crystallising forces had set up. This agent is a solar beam, with which it first occurred to Professor Tyndall to make the following simple experiment in the autumn of 1857. He placed a large converging lens in the sunbeams passing through a room, and observed the place where the rays were brought to a focus behind the lens; then, shading the lens, he placed a clear cube of ice, so that the point of convergence of the rays might fall within it. On removing the screen from the lens, a cone of sunlight went through the cube, and along the course of the cone the ice became studded with lustrous spots, evidently formed by the beam, as if minute reflectors had been suddenly established within the mass from which the light flashed when it met them. On examining the cube afterwards, he found that each of these spots was surrounded by a liquid flower of six petals. Such flowers were distributed in hundreds through the ice, being usually clear and detached from each other, but sometimes crowded together into liquid bouquets, through which, however, the six-starred element could be plainly traced. When the ice was held at a suitable angle to the solar beams, these liquid blossoms, with their central spots shining more intensely than burnished silver, presented an exhibition of beauty not easily described.

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[1] 'The Glaciers of the Alps,' p. 130. 1860.

[2] Ibid. p. 212–215. 1860.

'Such are the wonders lavished on a block of common ice, and thus artistically Nature operates throughout the world, wherever frost binds water in crystal fetters. Every atom of the solid ice which sheets the frozen lakes of the North has been fixed according to this law. Nature lays her beams in music, and it is the function of science to purify our organs, so as to enable us to hear the strain.'[1]

Generally, during the same snowfall, the flakes assume but one form—seldom more. Probably this difference results from the temperature, the quantity of moisture, and the motion of the air, which prevail at the time, for it has often been observed that a change of temperature produces a change in the form of the snow-flakes.

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[1] 'The Glaciers of the Alps,' p. 110.

Sometimes the snow falls during serene weather in the form of fine ice needles, which, though somewhat tarnishing the clearness of the atmosphere, do not render it opaque like clouds. In our latitudes these fine crystals fall but in small numbers; but, in the Arctic regions, this mode of snow formation is much more frequent; and the quantity of *snow dust* is often very great. During his stay at Port Bowen, Parry witnessed its fall more than once during clear weather, and even when not drifted by the wind, it covered the ground to the depth of four or five inches. The formation of snow-dust in the frigid zone is often accompanied with a mist which penetrates into a room through the narrowest crevices, and like hoarfrost covers the beds and their occupants with fine needles of ice.

In the temperate latitudes the snow generally falls when the sky is obscured, and the wind, after a severe cold, turns to the west. It has even been supposed that no snow can form when the cold is very intense, but Kämtz observed several snowfalls at Halle (in Prussian Saxony), which took place at the low temperatures of −5°, −8°, and −10° F.

In England snow usually falls when the atmosphere is comparatively calm. Sometimes, however, it is accompanied with stormy weather—a change of the wind from W. through NW. to N.—and a biting cold. When the wintry blast thus furiously drives before it the whirling snow, obliterating the roads and whelming the whole country under an undistinguishable pall, the snow not seldom becomes fatal to the hapless wanderer, who, unable to find his way through the pathless waste, falls a victim to fatigue and frost.

As thus the snows arise, and, foul and fierce,
All winter drives along the darkened air,
In his own loose-revolving fields, the swain
Disaster'd stands, sees other hills ascend,
Of unknown joyless brow; and other scenes,
Of horrid prospect, shag the trackless plain;
Nor finds the river, nor the forest, hid
Beneath the formless wild; but wanders on
From hill to dale, still more and more astray;
Impatient flouncing through the drifted heaps,
Stung with the thoughts of home: the thoughts of home

Rush on his nerves, and call their vigour forth
In many a vain attempt. How sinks his soul!
What black despair, what horror fills his heart!
When for the dusky spot, which fancy feigned
His tufted cottage rising through the snow,
He meets the roughness of the middle waste,
Far from the track and blest abode of man:
While round him night, resistless closes fast,
And every tempest, howling o'er his head,
Renders the savage wilderness more wild.
Then throng the busy shapes into his mind
Of cover'd pits, unfathomably deep,
A dire descent! beyond the power of frost;
Of faithless bogs; of precipices huge,
Smooth'd up with snow; and what is land, unknown,
What water, of the still unfrozen spring,
In the loose marsh or solitary lake,
Where the fresh fountain from the bottom boils.
These check his fearful steps; and down he sinks
Beneath the shelter of the shapeless drift
Thinking o'er all the bitterness of death,
Mix'd with the tender anguish nature shoots
Thro' the wrung bosom of the dying man,
His wife, his children, and his friends unseen.
In vain for him th' officious wife prepares
The fire fair-blazing and the vestment warm;
In vain his little children, peeping out
Into the mingling storm, demand their sire,
With tears of artless innocence. Alas!
Nor wife, nor children, more shall he behold,
Nor friends, nor sacred home. On every nerve
The deadly Winter seizes; shuts up sense;
And o'er his inmost vitals creeping cold,
Lays him along the snows, a stiffened corse,
Stretch'd out, and bleaching in the northern blast.—THOMSON.

In mountainous countries, on bleak plateaux and generally in the colder regions of our globe, where the snowstorms often arise with terrible fury, they even rival the tropical hurricanes in destructive fury. Thus in the year 1827 all the herds of the small Kirghiz horde were driven by a snowstorm to Saratow, and no less than 280,000 horses, 30,000 oxen, 10,000 camels, and more than a million of sheep, perished on the way.

Many a traveller, while attempting to cross in winter one of the high Alpine passes, has fallen a victim to the pitiless snowstorms of that bleak and inhospitable season. On January 6, 1863, a dreadful tempest swept over the Alps from south to north. Thick masses of snow soon effaced all the small inequalities of the soil, and rendered all communications impossible. At the same time the Fön raged with indescribable fury, uprooting numberless trees, carrying away the roofs of houses and stables, and even blowing down buildings. The church bells, set in motion by the wind, accompanied the uproar of the elements with a mournful toll. All the post-carriages which on that day had set off from the southern slopes of the Alps were obliged to stop at the last village at the foot of the mountain passes, as the snow rendered the continuance of their journey impossible. The Simplon, the Splügen, the Gotthard, and the Bernhardin, were all equally closed; and even the Julian, the tamest of all the Alpine passes, which had never been obstructed since the road was made, was now completely blocked. In the course of a few hours the snow had fallen to a height of three or four yards, so that the Splügen diligence was detained four days at Campodolcino, a wretched hamlet on the Italian frontier, as it was found impos-

AN ALPINE SNOW SCENE.

sible both to continue the journey or to return to Chiavenna, in spite of the utmost exertions of the villagers to open the road.

The passage of the Cordillera in winter is rendered extremely dangerous by the snowstorms, which rage with indescribable fury. They sometimes arise with astonishing rapidity, and often with such insignificant premonitory signs that it requires all the keen-sighted attention of the inhabitants, whom necessity has made sharp observers of the weather, to foretell and to avoid the impending danger. In some passes houses of refuge have been built, as in the Alps, or in Norway, but even then a timely escape is often impossible to any one overtaken by one of these dreadful storms. Tschudi mentions that but few instances are known where a muleteer escaped a snowstorm on the pass between Molinos and Atacama by abandoning his beasts of burden and flying for his life on a swift-footed mule. A few weeks before his arrival in Atacama a wealthy young man of the province of Saltos had ventured, in spite of all the warnings of his friends, to cross the pass at a time when snowstorms usually occur. He fell a victim, with his attendants, to his foolhardy undertaking. About a fortnight later their bodies were found by some chinchilla hunters.[1]

The snowstorm which, on the first days of January, 1873, raged over the north-west of the United States, and particularly over Minnesota, will long be remembered by the people who suffered from its fury. No less than 3,000 persons are said to have become its victims, for such was its violence, that it was almost impossible for those who encountered it in the open air to save their lives. Many wanderers and waggoners were so blinded by the whirling drift that they missed the road, and, unable to regain their homes, perished from frost and hunger. Whole houses were completely buried under the snow; their chimneys projecting like grave-stones over the vast white funereal pall which covered the whole country.

On January 10 a number of Swedish settlers had left New Ulm in sledges to return to their respective farms, and of these, as far as was known, eighteen never lived to see them again. The death of thirty-seven persons was reported from Redwood Falls. Along the telegraphic line between St. Paul and Sioux City thirty-seven persons perished from frost. The subsequent melting of the snow, and the heavy rainfalls which followed, caused the rivers to swell. On January 18, 19, and 20, the destruction of the bridges interrupted all railroad communication in many places, and added new distress to the existing misery. The bitter cold which accompanied the snowstorm did not produce the same chilling sensation as in damper climates; it attacked its victims in an imperceptible and insidious manner. As they rode on, an agreeable drowsiness crept over them, the objects along the road became indistinct, their thoughts began to wander, their memory failed them, and in a confused dream of family and home, they fell into their last sleep, contented, and without pain.

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[1] 'Reisen durch Süd Amerika,' von J. J. von Tschudi, vol. v. p. 74. Leipzig. 1869.

But it is not only when the gale drives it along in furious eddies through the air that the snow endangers life on the high Alpine passes. Frequently also it rushes down the mountain flanks in prodigious masses, which overwhelm and crush all that comes within their reach. When in winter or early spring a great quantity of loose soft snow falls upon a declivity of rock or slippery ice, then the slightest cause—the step of a chamois, or a tiny snowball falling from a shrub and rolling along—suffices to set enormous quantities in motion. First slowly, then faster and faster, and finally with frantic rapidity; first insignificantly small, then greater and greater, and waxing to gigantic proportions—the lavines, formidable both by their enormous weight and their dreadful speed, thunder down into the vale beneath.

The commotion of the atmosphere which they occasion gives rise to new falls from the neighbouring slopes, until at last whole snow-fields are carried along in the furious race. Immense clouds of snow-dust hide the course of the lavine from the view, but the horrid tumult strikes the ear with deafening noise; the ground trembles as if shaken by an earthquake. One feels that behind that misty veil a prodigious might is forcing its way through every barrier that impedes its progress; and then a deep silence follows upon the terrible uproar, as if the demon powers were resting after their frantic exertions.

But a few minutes have elapsed between the first imperceptible beginning of the snowfall and the peaceful termination of its wild career, but these few minutes have sufficed to mow down forests like blades of grass, to destroy the happiness of many families, and to plough a wide furrow of utter devastation from some high Alpine pasture ground to the stream which rushes along far down in the valley.

In these dreadful catastrophes the lavine itself is not the only agent of destruction; the air currents also which accompany its path rival it in destructive rage. Sweeping along on both sides of the snow-current, they shoot forwards far beyond the spot where it comes to rest, and frequently bound against the opposite mountain, or rush down the valley with all the fury of a hurricane.

'In the forests,' says Tschudi, 'the air currents uproot the strongest trees on both sides of the snow-stream; they lift men and animals, and hurl them into the abyss; they throw down heavy waggons, and carry away whole huts and stables like chaff. With the wind a large mass of snow-dust is swept along, which penetrates into the houses through the smallest chinks and crevices, and sticks so fast in the clothes that it cannot be brushed away.'

Besides these large destructive lavines, which are fortunately comparatively rare, numberless small snowfalls are constantly occurring in the Alps. They are seen hanging like veils on the precipitous rock walls, or shooting down a gully, and finally terminating their short career in some solitary cauldron. They are everywhere welcomed as the jovial, boisterous heralds of spring, and to see them rush like cataracts from ridge to ridge along the channels which ages have furrowed in the desolate flanks of some giant mountain, like the Jungfrau or the Wetterhorn, is one of the grand sights of Switzerland. In most cases the descent of an avalanche is announced by the sound, but sometimes the white mass is seen gliding down the rock and scattering its smoke in the air long before the sound reaches the spectator's ear. The insignificant appearance presented by avalanches, when seen from a distance, seems out of proportion with their thundering noise, but a closer inspection of the huge masses thus set in motion fully accounts for it. One block of solid ice recently detached from the Heisse Platte, in the Ice Sea of the Grindelwald Glacier, was found by Professsor Tyndall to measure 7 feet 6 inches in length, 5 feet 8 inches in height, and 4 feet 6 inches in depth. A second mass was 10 feet long, 8 feet high, and 6 feet wide. It contained, therefore, 480 cubic feet of ice, which had been cast to a distance of nearly 1,000 yards down the glacier. The shock of such enormous projectiles against rocks and ice, reinforced by the echoes from the surrounding mountains, may well give rise to sounds emulating the peals of thunder or the roar of artillery.

The disastrous effects which snow sometimes produces when it rides on the pinions of the gale, or rushes down in destructive avalanches, are far outweighed by its services.

> Fast falls a fleecy shower: the downy flakes
> Descending, and with never-ceasing lapse,
> Softly alighting upon all below,
> Assimilate all objects. Earth receives
> Gladly the thick'ning mantle; and the green
> And tender blade, that fear'd the chilling blast,
> Escapes unhurt beneath so warm a veil.—COWPER.

The hardy plants of the polar regions entirely owe their existence to the snow, which screens them in an admirable manner from the intense cold of an Arctic winter. For snow is so bad a conductor of heat that in the high latitude of 78·50° (Rensselaer Bay), while the surface temperature was as low as −30°, Kane found at two feet deep a temperature of only −8°; at four feet +2°; and at eight feet +26°, or no more than six degrees below the freezing-point of water. Thus, covered by a warm mantle of glittering crystals, plants more numerous than might be expected in the regions of almost perpetual frost pass the long winter in a comparatively mild temperature, high enough to maintain their life; while without, icy blasts, capable of converting mercury into a solid body, howl over the naked wilderness; and as the first snowfalls are more cellular and less condensed than the almost impalpable powder of winter, Kane justly observes that 'no eiderdown in the cradle of an infant is tucked in more kindly than the sleeping dress of winter about the feeble plant-life of the Arctic zone.' Thus it is owing to the snow which covers their dreary solitudes that the most northern countries of the globe, as far as man has been able to advance towards the Pole, are not entirely deprived of the summer ornament of flowers, that the ranunculus adorns the wastes of Melville Island, and the forget-me-not blooms in Novaya Zemlya.

POLAR BEAR.

The few animals that spend the winter on the plains or along the coasts of the Arctic lands likewise owe their existence to this sheltering mantle. Under the snow the lemming makes long passages in search of the juicy stems of the willow, and snow warms also the burrow of his arch-enemy the Arctic fox. Such is the warmth-retaining power of snow that, guided by a beautiful instinct, the female polar bear voluntarily seeks its cover to pass the winter in what might be called an improvised cave. Towards the month of December she retreats to the side of a rock, where, by dint of scraping, and allowing the snow to fall upon her, she forms a cell, in which she produces her young, and remains with them until the month of March, when she emerges into the outer air, with her diminutive offspring, who are then no larger than ordinary rabbits. As the time passes on, the breath of the family, together with the warmth exhaled from their bodies, serves to enlarge the cell; so that in proportion with their increasing dimensions the accommodation is increased to suit their growth.

In a similar manner the experienced traveller, when overtaken by a furious snowstorm, in some pathless waste, far from the habitations of man, finds in the heavy flakes falling thickly around him the best protection against the fatal embrace of frost. Choosing some spot where the snow lies deepest, he scoops out with his hands a hollow in which he can lie sheltered from the icy blasts that howl over the land. Wrapping himself in his garments, he burrows his way as deeply as he can, and then lies quietly, allowing the snow to fall upon him unheeded. The extemporised cell in which he reclines soon begins to show its virtues, for the caloric exhaled from his body is no longer swept off by the wind, but conserved around him by the slow conducting snow, restores warmth and sensation to his limbs. The hollow enlarges slightly as the body becomes warm, and allows its temporary inhabitant to sink deeper into the snow, while the fast falling flakes rapidly cover him, and obliterate the traces of his presence.

In this situation he need not fear being stifled for want of air, for the warmth of his breath always keeps a small passage open, and the surface of the snow is broken by a little hole, round which is collected a mass of glittering hoar-frost, caused by the congelation of the breath. Even in the British Islands the snow-bed has saved the life of many a wanderer who knew how to avail himself of its protecting warmth, and the walrus-hunter of Spitzbergen or Bear Island has often, thanks to the shelter which it afforded, been able to weather unharmed the howling snow tempests of the North.

In the Scottish Highlands, after the wintry blast has piled up enormous snow-drifts in all kinds of fantastic shapes, whole flocks of sheep are sometimes missing, and must be sought by the shepherd and his faithful dog. All the well-known landmarks have been effaced; hills rise where hollows were before, and the whole face of Nature is changed. Left to himself the shepherd would soon be bewildered in the snowy maze, but his sagacious companion, guided by his admirable instinct, sniffs and runs about and raises his nose in the air to catch the well-known odour, and finally dashes forward and comes to a standstill over a little hole in the snow, which indicates that the sheep lie buried underneath. Then the shepherd breaks through the roof of the snowy cell with his pole and rescues the starving flock, which, huddled together to avoid the cutting wind, had effectually been imbedded in the snow.

On the Great St. Bernard the wanderer often escapes being frozen to death by means of the warm snow mantle which gathers over him when he sinks down exhausted from his efforts to face the storm. Here also the sagacious dog becomes his preserver, and points out to the Fathers of the Hospice the spot where he lies buried.

Between the eternal snows of the High Alps and the hills at their base, where the vine ripens its fruit, lies a zone where the snow melts more or less rapidly, according to its depth or the altitude of the situation. Even where it remains on the earth for eight or ten months, the ground is found covered after its disappearance with numerous herbs, which afford a delicious repast to the browsing goat. The grass is soon bespangled with countless flowers, whose buds were formed under the snow. It had often been vainly tried to naturalise these beautiful Alpine plants in our gardens, until a horticulturist fell upon the lucky idea of placing them in winter in a greenhouse, among the orange and pomegranate trees.

By this means plants originally growing in the high mountain wildernesses, where the thermometer in winter not seldom falls to 45° below the freezing-point of water, have been admirably preserved. For in the greenhouses they found the same shelter against the cold and the sudden changes of the spring temperature which they enjoy in their natural stations under a thick sheet of snow.

In many countries the slippery snow surface facilitates travelling and the transport of goods, which otherwise would be entirely stopped during a severe winter. In Russia it is considered a great disaster when the snow either fails or retards its fall, as then it is difficult to convey grain from the interior to the seaports, and to provide the towns with provisions and fuel for the long winter.

ST. BERNARD DOGS LOOKING FOR TRAVELLERS IN THE SNOW.

On his dog-drawn sledge the Esquimaux conveys the slaughtered seal to his wretched hut, which otherwise he would hardly be able to reach; and on his snow-shoes the Laplander flies like a bird over the crystal ground, now scaling the mountains by a tortuous ascent, and now darting down into the valley—

Ocior cervis et agente nimbos
Ocior Euro.

The proverbial whiteness of snow is due to the air entangled in its meshes, for whiteness always results from the intimate and irregular mixture of air and a transparent solid. 'A crushed diamond would resemble snow; if we pound the most transparent rock-salt into powder we have a substance as white as the whitest culinary salt; and the colourless glass vessel which holds the salt would also, if pounded, give a powder as white as the salt itself. It is a law of light, that in passing from one substance to another, possessing a different power of refraction, a portion of it is always reflected. Hence when light falls upon a transparent body mixed with air, at each passage of the light from the air to the solid, and from the solid to the air, a portion of it is reflected; and, in the case of a powder, this reflection occurs so frequently that the passage of the light is practically cut off. Thus, from the mixture of two perfectly transparent substances, we obtain an opaque one; from the intimate mixture of air and water we obtain foam; clouds owe their opacity to the same principle; and the condensed steam of a locomotive casts a shadow upon the fields adjacent to the line, because the sunlight is wasted in echoes at the innumerable limiting surfaces of water and air.'[1]

With the exception of the high mountain summits, which, rising above the perpetual snow line, maintain their glittering mantle even under the rays of a vertical sun, snow never falls in the tropics. In the northern hemisphere the limits of exclusive rain and exceptional snow meet in the Mediterranean to the south of Italy. During a period of ten years snow falls at Palermo on 16 days, at Rome on 26, at Venice on 56. On the hills it is of course more frequently seen, and though snow rarely falls in the streets of the ancient capital of the world, a winter rarely passes where it does not cover the summit of Soracte.

> Vides ut alta stet nive candidum
> Soracte.

In the lowlands of Algeria snow is a very rare phenomenon, and also in Spain, where only eminences above two thousand feet high are for a short time covered with snow.

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[1] Tyndall's 'Glaciers of the Alps,' p. 250.

But even along its southern limits snow sometimes falls in very considerable quantities. On November 29, 1849, snow fell at Rome half a foot high, and, during the following winter, which covered, among others, Mount Saint Bernard with a snow-mantle 45 feet thick, the environs of Athens were buried more than three feet deep under snow—a phenomenon beyond the memory of the oldest inhabitants. The Hymettus, the Pentelikon, and the Parnassus, formed one vast snow-field—an unusual sight for Apollo and the Muses, who must have felt rather chilly in their ordinary light costumes.

Farther to the north the frequency and the duration of snow constantly increase. In central Germany it seldom appears before November, though sometimes, indeed, as early as September (for instance, in 1871). Snow in May is not unfrequent, and on the first days of June, 1836, the streets of Wiesbaden, which generally boasts of a mild climate, were white with snow.

As the mean temperature of the air diminishes with its elevation above the level of the sea, a height must eventually be attained where, even in the tropics, the heat of the sun is unable to counteract the effects of the cold which reigns in the upper regions of the atmosphere, and the ground is covered with perpetual snow.

In the torrid zone the snow line, as this limit is called, occurs at a mean elevation of 15,800 feet; in the Pyrenees (42·30°—43° N. lat.) of 9,000 feet; in the Alps (45·45°—46·45° N. lat.) of 8,500; and thus on both sides of the equator it generally descends on advancing towards the poles.

The mean temperature of the summer has, however, so great an influence on the snow line that even in the same latitude we find considerable differences in its height. On the Swedish side of the Scandinavian mountains, for instance, the greater warmth of the summer causes it to ascend much higher than on the Norwegian side, where, in spite of the higher mean temperature of the year, the summer is colder and moister, and the snowfall is both more abundant and melts slower than in Sweden. On the eastern slopes of the South American Andes the snow is likewise found to dissolve at a much greater height than on their western side, where the influence of the sea produces a cooler summer, which consequently has less power to thaw the masses of snow accumulated during the winter, than the warmer and drier summer in the interior of the continent.

An extraordinary difference in height at a distance of only 9° of latitude is found to exist between the snow line on the Cordilleras, behind the island of Chiloe (lat. 41° to 43° S.), where it is met with at the low level of 6,000 feet, and in central Chili, where it rises to 15,000 feet. The coast opposite Chiloe is covered with one dense forest dripping with moisture. The sky is cloudy, and, though the land corresponds in latitude with the northern parts of Spain, the peach seldom produces fruit. In central Chili, on the other hand, a little northward of Concepcion (lat. 37°), the sky is generally clear; rain does not fall during the seven summer months, and southern European fruits succeed admirably.

According to Mr. Darwin, the plain of perpetual snow undergoes this remarkable flexure of 9,000 feet, unparalleled in other parts of the world, not far from the latitude of Concepcion, where the land ceases to be covered with forest trees; for trees in South America indicate a rainy climate, and rain a clouded sky and little heat in summer.

The Pyrenees and the Caucasus are situated in the same latitude, and yet in the Caucasian chain the snow line is about 2,000 feet higher, because its greater distance from the ocean, and consequently its drier air, causes a less abundant fall of snow during the winter, and at the same time promotes its dissolution and evaporation during the summer.

The influence of a dry continental summer is particularly striking in the Himalaya mountains, on whose southern slopes the snow line is more than 4,000 feet lower than on the northern side.

In the Alps, on the contrary, the snow line is generally somewhat lower on the northern side, on account of the warmer and clearer Italian atmosphere, and of the frequent warm southerly winds, which of course exert a greater influence on the southern slopes.

Many of the Alpine peaks which rise above the ordinary limits of the snow line are still completely denuded of snow during the summer on account of their distance from the chief mass of the mountains. In other places, where a great number of snow mountains are crowded together, the perpetual snow frequently descends to a level where it would disappear every summer on isolated peaks. Such is the influence of the cool summer in the Strait of Magellan that the snow line descends as low down as 3,500 or 4,000 feet above the level of the sea, while in Norway we must travel to between lat. 67° and 70° N., that is about 14° nearer to the pole, to meet with perpetual snow at this low level.

In consequence of the higher summer temperature in the Arctic regions, there is no land known in the North Polar zone where the snow line descends as low as the sea-shore; for even in Novaya Zemlya, where the summer developes less warmth than in any other of the larger polar countries, the flat coasts are snowless during this season of the year, while in the Antarctic wastes Sir James Ross found in summer the shores of Victoria Land (71°–76° S. lat.) covered with snow under the same latitude as Norway (71° 15′–71° 30′ N. lat.), where the snow line ascends to 2,500 feet. In South Georgia (lat. 54°), Captain Cook found in summer the coasts covered in many places with snow, and in Sandwich Land, the latitude of which corresponds with that of the Shetland Islands, he saw on February 1, in the warmest season of the southern hemisphere, the whole land covered with snow many fathoms deep, from the summit of the mountains to the foot of the cliffs along the coast.

As might be expected, the snow line varies exceedingly in height in different summers. Mr. Darwin was assured that during one very long and dry summer all the snow disappeared from Aconcagua, although this monarch of the Andes attains the prodigious height of 23,000 feet. Tschudi[1] likewise mentions that in very warm summers the *Misti*, or the volcano of Arequipa (20,300 feet), is completely free of snow. This phenomenon is by no means agreeable to the inhabitants of Arequipa, for a proverb says, 'When the Misti has no snow, doctors and priests have a good income.'

In spite of the eternal snow mantle which covers the high mountains, they are by no means the seat of perpetual frost, for even in winter sunny days may be very warm above the snow line. The guides, Melchior and Jacob Blatter of Meyringen, and Gorret of Val Tournanche, who were engaged by Mr. Dollfus to make meteorological observations during a whole year (from August, 1865, till August, 1866) on the Theodule Pass (10,280 French feet), frequently express in their diary their astonishment at the warmth of the sun, and the splendour of its rays in the season of snow and frost. 'On such a fine winter's day,' they write (Diary, December 21), 'one feels here on high quite young.' During a strong wind the sun warms the air scarcely perceptibly, but very much so when the atmosphere is quiet. The snow then often melts at a temperature of 6° F. The winter of these high mountain lands is distinguished by a relative and absolute dryness of the atmosphere, which occasions a serene sky, and allows the rays of the sun to strike with full force upon the ground. The region in which clouds are principally formed descends in winter to a low level, so that while gloom envelopes the plains, a beautiful sunshine generally rests upon the brow of the mountains.

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[1] Tschudi, 'Reisen in Süd Amerika,' Leipzig, vol. v. p. 352. 1869.

The snow which fell in winter upon the Theodule Pass was generally in the form of a fine dust like that of the Arctic regions; on May 29 it fell again for the first time in large flakes, as in the plains. Its quantity was relatively small, not exceeding 2·4 metres during the whole winter. The strongest snowfalls within twenty-four hours amounted to no more than 0·6 metre, while in many Alpine valleys they frequently attain a depth of 2 metres.

Though the heat of the sun is so powerfully felt above the snow line, the warm hours and days are too short to remove the large masses of snow which fall during the colder periods, so that year after year new layers of snow are piled up one above the other. Where these accumulations are terminated by an abrupt declivity, and their internal structure becomes visible, it is easy to distinguish the successive annual strata by the bands of dust or sand which the wind sweeps down in summer from the naked rocks.

Thus the snow would be perpetually accumulating on the high Alps, and ultimately induce a new glacial period, if new counterforces did not come into action. But, with the growth of a nevé or snow-field, the declivities along its sides become more abrupt, and at the same time the weight increases, which presses upon its lower and older strata, and tends to displace them, so that finally the mass is forced to move downwards to a level where, exposed to the influence of a warmer temperature, it melts and flows away.

The displacement from the position which it originally occupied takes place either suddenly in thundering avalanches, or gradually and imperceptibly in the glaciers, which issue like ice-streams from the nevé, or glacial sea (Mer de Glace) above the limits of perpetual ice, and sometimes descends as low as 4,000 or 5,000 feet beneath the snow line. These streams of crystallised water form in summer a remarkable contrast to the inclosing mountain slopes, which are often covered with woods or flowery herbage in the immediate vicinity of the ice. Thus, in the vale of Chamouny, several glaciers nearly reach its lowest level, and the extremity of the Lower Grindelwald Glacier is only 3,000 feet above the surface of the sea. There death and life, winter and summer, are brought into wonderful proximity. On one side the

GLACIER.

rigid ice stream, waste and empty like the earth on the day of creation, and close by luxuriant pastures, sweet smelling herbs and trees of powerful growth—a spectacle which, by the charm of contrast, is one of the most interesting of the glorious Alpine world. Apparently immovable as the rocks which enclose it, the ice of the glaciers still moves as uninterruptedly onward as the rolling waters of a stream. Thus it has been found by accurate measurements that the central parts of the Mer de Glace near Chamouny advance in summer at the rate of twenty inches a day—a progress which, towards the lower ice cascade, increases to thirty-five inches daily. In winter the rapidity is only about half as great. Along the borders of the glacier and in its deeper strata the progressive movement is likewise less rapid than in its superficial central parts. In short, the ice of the glacier obeys as it moves along the same laws as a stream of water, advancing more or less rapidly according to its volume, the inclination of its bed, and the various circumstances which retard or favour its progress. While its lower end is wasting away under the influence of the summer heat, new masses from the inexhaustible and constantly replenished stores of the nevé are perpetually pressing forwards to make up for the loss, and thus it glides along slowly, but irresistibly, as time imperceptibly passes away on its march to the ocean of eternity.

The fact of glacier motion had long been known to the inhabitants of the mountains before it attracted the attention of scientific men. The first who made quantitative observations of the motion was Hugi. He found that from 1827 to 1830 his cabin upon the glacier of the Aar had moved 100 metres, or about 110 yards, downwards; in 1836 it had moved 714 metres; and in 1841 M. Agassiz found it at a distance of 1,428 metres from its first position. This is equivalent, in round numbers, to an average velocity of 100 metres a year. Since then the labours and accurate measurements of Rendu, Forbes, and Professor Tyndall, have fully ascertained the laws which regulate the motion of glaciers, and satisfactorily explained their various phenomena.

The cataract bounding over rocks soon reaches the plains; but the ice of the glacier frequently requires a century or more to perform its march from one end to the other of the frozen stream, so that its sojourn in the mountains outlasts the life of the oldest patriarch of the Alps. The tourist who, in the plenitude of youth and strength, crosses the upper portions of a glacier, will long have been gathered to his fathers ere the ice on which he treads, or the crystal pyramid he sees glittering above, has performed its journey to the glacier's end.

But, though its progress is so slow, the force with which the glacier presses onwards is irresistible, and human power would be as utterly unable to oppose it, as to cause the lava stream to stop, or to stem the swelling tide. 'When after a succession of cold summers,' says Professor Helmholtz, 'attended with copious snowfalls on high, the lower end of a glacier advances, it not only sometimes demolishes human dwellings, or snaps large trees asunder, but shoves along the mounds of its end moraine composed of enormous blocks of stone without any apparent sign of their affording the least obstacle to its onward march. A truly magnificent spectacle this movement—so quiet, so continuous, and so irresistible and mighty.'

As a stream, according to the condition of its bed, now flows quietly along and smooth as a mirror, and now tumultuously rushes onwards, curling its turbulent waters into waves, thus also the surface of the glacier is sometimes even and unbroken, and then again resembles an agitated sea torn with tempestuous billows. The greatest disruptions in the glacier's surface naturally takes place where, supposing it to consist of water, cascades would be seen rushing down an abrupt declivity. In these places, which resemble a cataract suddenly frozen in its fall, the ice is split in all directions into a number of separate blocks, which, in consequence of their partially melting, are changed into singularly formed reefs and pyramids, and from time to time fall with a tremendous crash into the deep crevices between them.

The surface of most glaciers, particularly towards their extremity, is soiled by the covering of earth, sand, and stones, which collects upon them, but at a greater depth the ice is of incomparable purity, and of a colour of the brightest azure. The formation of the crevices takes place as imperceptibly as the motion of the glacier by which they are caused. At first they are narrow splits, hardly admitting the edge of a knife, and then, as the ice is slowly shoved along, they gradually widen into large clefts and enormous precipices, which are sometimes more than a thousand feet long, fifty or a hundred feet wide, and not seldom of immeasurable depth. Their precipitous dark blue walls afford a truly magnificient spectacle, but woe to the heedless chamois hunter or Alpine traveller who falls into the yawning abyss.

In July, 1836, the guide Michael Devouasson fell into a crevice on the Glacier du Talèfre, from which he was able to extricate himself by means of a pocket-knife with which he cut steps into the ice. Ten years later his bag, which he had lost in the crevice, came to light 4,400 feet lower down, at the foot of the Couvercle.

On the Trift Glacier (Canton Bern), the chamois hunter, Peter Moor, of Gadmen, fell into a crevice, but fortunately upon a projection in the ice, which prevented his reaching the bottom of the yawning abyss. To save their unfortunate friend, his companions hastened to the nearest houses, which were several leagues distant, and did not return before the evening with the means of rescue. After the half-benumbed man had firmly tied the rope which had been thrown down to him round his body, and had been pulled up several feet high, the rope broke, and he fell down again upon the projection. The rope was now too short, so that his friends had to walk back again to the house in the night to fetch a stronger one. On the following morning they at length succeeded in delivering Peter Moor, after he had spent sixteen long and anxious hours in his icy dungeon.

The following case is still more wonderful. On July 7, 1787, Christian Bohren fell into a crevice 64 feet deep, while crossing the Upper Grindelwald Glacier. He broke an arm, and dislocated one of his hands, but fortunately preserved his presence of mind, which enabled him to avail himself of an opening under the glacier that had been hollowed out by the Weissbach, a streamlet flowing from the Wetterhorn. Creeping through this narrow passage, he with incredible difficulty worked his way out of the foot of the glacier, and thus providentially escaped being buried alive and perishing of cold and hunger.

In other cases the end has been more tragical. On August 28, 1865, two German students made the ascent of the Great Venediger, in Tyrol, and succeeded in reaching the summit. On their way back, one of them, W. Hinsch, a Holsteiner, slid without suffering any serious injury into a sloping crevice, where he remained jammed in with his breast and back at a depth of about one hundred feet. He cried out loudly for help, and said that his arms were free. But the improvident guide had neglected taking a rope with him, and the unfortunate youth was told that eight hours at least would elapse before he could be hauled up. 'I shall not be able to hold out so long,' was his resigned answer; 'Adieu, my friend; remember me to my parents.' The friend made all haste with the guide to the next cottage, where, however, no rope was to be found, so that they had to descend as far as the village of Neukirchen, where they arrived seven hours after the accident had taken place. Here the wretched guide refused to return to the fatal crevice, so that the friend, accompanied by five other strong men, was obliged to re-ascend the mountain a second time. On the following morning at eight o'clock they reached the crevice. One of the men was lowered down into it, about fifty feet deep, where the narrowness of the crevice stopped his further descent. Far below he saw the corpse of the unfortunate youth; his head reclining on one side, and sleeping the deep sleep of death!

Generally the glacier melts away at its extremity as quietly and imperceptibly as it advances, but in a few rare instances comparatively small glaciers lying on a steep rocky slope have been known to detach themselves wholly or partially from their beds, and to fall into some lower valley. When this occurs in the neighbourhood of inhabited places the result is a catastrophe, as formidable as that caused by the fall of portions of a mountain.

Thus in the year 1636 a great part of the Weisshorn Glacier fell into the valley of St. Nicholas (Canton Wallis), and buried almost the whole village of Randah under its ruins. In the last century two similar ruptures of the glacier took place; and on December 29, 1819, the hurricane blast occasioned by the sudden fall of about 360,000,000 cubic feet of ice tore whole houses from their foundations, and hurled their ruins into the forest which lies high above the village. Sometimes also the fall of a glacier issuing from a lateral valley entirely blocks up the valley into which it descends, and converts a portion of it into a temporary lake by damming up the river. When, at a later period, the ice barrier, weakened by the summer heat, gives way under the pressure of the water, enormous floods rush down into the vale beneath.

Thus in 1818 the Gintroz Glacier blocked up the valley of Bagnes, one of the largest embranchments of the main valley of the Rhône, and by preventing the outflow of the Dranse, ultimately formed a lake about half a league in length, which finally attained in some parts a depth of about 200 feet, and a width of about 700 feet. To prevent or lessen the mischief apprehended from the sudden bursting of the barrier, an artificial gallery 700 feet in length was cut through the ice before the waters had risen to a great height. When at last they reached such an elevation as to flow through the tunnel they dissolved the ice, and thus deepened their channel until nearly half of the whole contents of the lake were slowly drained off. But at length, on the approach of the hot season, the central portion of the remaining mass of ice gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. In the course of their descent the waters encountered several narrow gorges, and at each of these they rose to a great height, and then burst with new violence into the next basin, sweeping along rocks, forests, houses, bridges, and cultivated land. For the greater part of its course the flood resembled a moving mass of rock and mud, rather than of water. Some blocks of granite, which from their dimensions might be compared without exaggeration to houses, were torn out of a more ancient alluvium, and borne down for a quarter of a mile. The velocity of the water in the first part of its course was thirty-three feet per second, which diminished to six feet before it reached the Lake of Geneva, where it arrived in six hours and a half, the distance being forty-five miles. This flood left behind it on the plains of Martigny thousands of trees torn up by the roots, together with the ruins of buildings. Some of the houses in that town were filled with mud up to the second storey.

The devastations did not end with this first impetuous outbreak, for the Dranse having no settled channel, shifted its position continually from one side to the other of the valley, as if determined to do as much mischief as it could. Sir Charles Lyell visited the valley four months after the flood, and was witness to the sweeping away of a bridge, and the undermining of part of a house. The greater part of the ice barrier was then standing, presenting vertical cliffs 150 feet high, like ravines in the lava currents of Etna, where they are intersected by rivers.

Inundations precisely similar are recorded to have occurred in former periods in the valley of Bagnes, and from the same cause. In 1595, for example, a lake burst, and the waters descending with irresistible fury, destroyed the town of Martigny, where from sixty to eighty persons perished. In a similar flood, fifty years before, 140 persons were drowned.

In the Tyrol the Hoch Vernagt Glacier likewise throws a barrier across the Oetzthal, and impedes the outflow of the Rofensee. This small lake burst in 1846, and devastated the whole valley of the Oetz. The three following years, particularly 1848, were likewise marked by great inundations. The last rupture has left an opening, and the Rofensee now freely discharges its waters; but since 1865 the glacier is again advancing, and menaces the valley with future inundations. Thus there are unfortunate districts which, in consequence of implacable natural laws, must inevitably be the scene of repeated catastrophes; and yet man remains true to the glebe which proved fatal to his fathers, and is sure to bring ruin to him or to his sons.

In the Polar regions, where numerous glaciers descending to the level of the sea protrude their crystal fronts far out into the bays or friths of Greenland or Fuegia, their extremities undermined by the waters, and exposed to the upheaving power of the tides, at length give way, and plunge into the deep with a crash louder than thunder. Drifted along by the winds and the ocean currents, the icebergs thus formed are conveyed to lower latitudes, where they ultimately melt away. Their size is frequently so enormous that they fully deserve the name of floating islands; but when we consider the vast scale upon which the parent glaciers of the Arctic zone are constructed, we cease to wonder at their dimensions. These colossal bergs have a considerable influence on the weather, and it is not improbable that when they are drifted in unusually greater numbers into the northern Atlantic, we have to feel the effects in a cold spring or a late summer. On reaching a lower latitude they must necessarily condense the aqueous vapour of the air round their icy summits; fogs and clouds are the consequence, and thus an impulse is given to atmospherical revolutions that may extend to an immense distance from the point where they originated. Many a vessel has also been lost in the Atlantic by striking against one of these floating rocks.

When the Greeks invented the legend of the Symplegades, those deep blue movable cliffs which opened and closed so as to crush everything that came between them, they had no idea that beyond the pillars of Hercules, in the distant unknown ocean, crystal rocks were floating far more wonderful than those which, fixed by the tones of Orpheus's magic lyre, allowed the Argonauts to sail unhurt into the Euxine, and that the fictions of their imagination were far surpassed by reality.

Thus also many an unknown wonder of Nature is still veiled from our gaze; and to future generations, penetrating deeper than ourselves into the great ocean of knowledge, is reserved the discovery of many facts as undreamt of by the science of our days, as the existence of the swimming icebergs of the north to the philosophers of ancient times.

The cause of glacier motion is a question too interesting to be passed over in silence. It may well be asked by what power a substance apparently so rigid as ice is forced to glide thus slowly and imperceptibly onwards, and to obey laws agreeing very closely with those which govern the flow of rivers. Omitting all mention of old and long since exploded explanations, I will merely state that, according to an hypothesis first hinted by Rendu, and since worked out by

Forbes, ice, instead of being solid and compact, is a viscous or plastic body capable of yielding to great pressure, and the more so in proportion as its temperature is higher, or as it approaches more nearly to the melting point. Many examples were adduced by Forbes to prove that a glacier can model itself to the form of the ground over which it is forced exactly as would happen if it possessed a certain ductility, and this power of yielding under intense pressure was supposed not to be irreconcilable with the idea of the ice being sufficiently compact to break into fragments when the strain upon its parts is excessive, as when the glacier turns a sharp angle, or descends upon a rapid or convex slope.

To this theory Professor Tyndall objected that it would account for a part only of the facts. Ice, he admitted, deports itself as a viscous body in cases where it is subjected to pressure alone; but when tension comes into play, the analogy with a viscous body ceases. 'The glacier widens, bends, and narrows, and its centre moves more quickly than its sides; a viscous mass would undoubtedly do the same. But the most delicate experiments on the capacity of ice to yield to strain—to stretch out like treacle, honey, or tar—have failed to detect this stretching power. Is there,' he asks, 'then, any other physical quality to which the power of accommodation possessed by glacier ice may be referred?'

Faraday had called attention in 1850 to the fact that, if two pieces of ice, having throughout a temperature of 32° F., and each melting at its surface, are made to touch each other, they will freeze together at the points of contact.

This phenomenon, which is now known under the name of regelation, is easily explained. The particles on the exterior of a block of ice are held by cohesion on one side only. When the temperature rises above the freezing-point of water, these exterior particles being partly free are consequently the first to pass into the liquid state, and a film of water covers the solid. But the particles in the interior of the block, being bounded on all sides by the solid ice, have no tendency to pass into a liquid, even when the whole mass is at 32° F., each particle being controlled on all sides by its neighbours. If the block be now split in halves, a liquid film instantly covers the fractured surfaces, for the force of cohesion on the broken surfaces has been lessened by the act. By placing the liquefying surfaces close together, so that their original position shall be regained, the liquid films on the two fractured surfaces again become bounded by ice on both sides. The film being excessively thin, the force of cohesion is able to act across it; the liquid particles consequently pass back into the solid state, and the block is reunited by regelation.

In virtue of this property ice may be made to take any shape we please. By passing, for example, a straight bar of ice successively through a series of moulds, each more curved than the last, it may finally be turned into a ring. The straight bar, on being squeezed into the curved mould, breaks, but by continuing the pressure new surfaces come into contact, and the continuity of the mass is restored.

Regelation even takes place by mere contact without any great pressure being used. Faraday found that on placing a number of small fragments of ice in a dish of water deep enough to float them, regelation instantly set in when one piece touched the other, even at a single point. Thus a train of pieces may be made to touch each other, and after they have once so touched the terminal piece of the train may draw all the others after it. On seeking to bend two pieces thus united at their point of junction the frozen points suddenly separate by fracture, but at the same moment other points come into contact, and regelation again binds them together.

The formation of a snowball is an instance of regelation. At temperatures below the freezing-point of water the snow is dry, and, on being squeezed, is unable to coalesce into a mass, but when the snow is at 32° and moist, pressure, by bringing the surfaces of its particles into close contact, easily converts it into a solid ball.

The snow-bridges also which span wide chasms in the Alps and elsewhere, and over which men can walk in safety, owe their solidity to the regelation of the snow-granules. By carefully treading down the mass, and thus causing its granules to regelate, the climber converts loose snow into firm ice, and crosses without fear fissures of an enormous depth.

The effects of regelation thus shown on a small scale fully account for the grand phenomena of the formation and motion of glaciers. By the heat of the sun, and the consequent percolation of water melted from the surface, the lower portions of the nevé are raised to 32°; at the same time, this part is closely pressed together by the weight of the snow above; regelation consequently sets in, converting the loose snow into solid ice. Its own gravity, with the enormous pressure from above, urges downwards the glacier, which, by virtue of regelation, constantly moulds itself to the form of the bed over which it passes, as if it were a pliable, viscid mass. It is easy to understand how a substance so endowed can be squeezed through the narrow gorges of the Alps, how it splits and is crushed and broken when forced through narrow channels or down abrupt declivities; and how, as it emerges from the gorge that confined it, its separate blocks again become reunited by regelation, and spread out in a uniform sheet, even as the cascades of a mountain torrent, bubbling and foaming in separate streamlets in a narrow pass, unite and flow on peaceably together when their bed widens and its slope diminishes.

The pressure to which the lower portions of the nevé are subjected, as new masses constantly accumulate above the snowfalls of previous years, removes them more and more from their original opaque condition. The air-bubbles which give the nevé ice its whiteness are more and more expelled, and this process continued throughout the entire glacier finally brings the ice to that beautiful state of transparency which we admire in the azure crevices of the glacier, or in the caves which the speculative Swiss have hewn at the terminal ends of the glaciers of Grindelwald, Rosenlaui, and elsewhere.

CHAPTER XVI.

THE THUNDERSTORM.

The Thunderbolts of Jove—Augural Importance of the Thunderstorm among the ancient Etruscans and Romans—Persons Struck by Lightning deemed Favourites of the Gods—True Nature of Lightning Surmised by Dr. Wall and Abbé Nollet, and Discovered by Franklin—His Experiments with a Kite—Experiments of d'Alibard and De Lor—Death of Professor Richman—Causes of the Thunderstorm—Premonitory Signs—Phenomena—A Thunderstorm Viewed from Above—In a Thundercloud—Various Forms of Lightning—Globular Lightning—Power of Lightning in Fusing Metals and Stones—Fulgurites—Mechanical Effects of Lightning—Good and Bad Conductors—Thunder—Thunder in the Alps—Distance at which Thunder can be heard—Height of Thunder Clouds—Death by Lightning—Exaggerated Alarms Ridiculed by Lichtenberg—Predilection of Lightning for Striking Certain Persons—Buildings and Ships Destroyed by Lightning—Death by Lightning Instantaneous—Curious Effects of Lightning—Cures Effected by Lightning—Geographical Distribution of Lightning Strokes and Thunderstorms in general.

THE sublime phenomenon of the thunderstorm has in all ages made a deep impression on the human mind. The dark and rapidly gathering clouds, the impetuous gusts of wind, the flashes of lightning, the rolling thunder, the torrents of rain—all combine to remind man of his weakness when opposed to the fury of the conflicting elements. Impressed with this idea, the Greeks armed the hand of Jupiter with the thunderbolt and the lightning—the dreaded weapons with which he hurled the Titans into the abyss; and when the thunder shook the sky the ancient Scandinavians fancied they heard their war-god Thor furiously bestriding the clouds, and triumphantly exclaiming—

Mine eyes are the lightning ;
The wheels of my chariot
Roll in the thunder.

In the Cosmogony of the Phœnicians[1] we find thunder and lightning playing an important part, for it was the awful voice of the storm which first caused the terrestrial animals and the fishes to start forth into life from the primeval slime which covered the face of the earth.

Bowdich relates that the Moors believe lightning to be occasioned by God waving his hand to direct the course of his angels.

According to the rude mythology of the Caribs, the rolling of the thunder is produced by the fall of the spirits pursued by Kualina, the chief of their deities; and a Lapland legend relates that the thunder-god Thiermes is incessantly pursued by Perkal, the devil. Muttering and growling, he roves through the skies, splitting trees and rending rocks, dispensing good and evil.

Thus in the sunny regions of the South, as in the desolate lands of the Polar world, among the various races of man, in different ages and in every stage of culture, we find the mighty influence of the thunderstorm expressed in sagas and legends.

But in the religion of no other people does this idea so prominently stand forth as among the ancient Etruscans, whose priests were supposed to be deeply versed in the interpretation of lightning,[2] according to the various circumstances attending their appearance, and in the art of eliciting them from the skies. Lightning, the sacred signal through which the gods revealed their will to man, preceded all other auguries in importance. If, for instance, the entrails of a victim, or the voice or flight of a bird, portended evil, and a favourable lightning flashed through the skies, the menacing omen lost all effect. On the other hand, the portent of lightning was irrevocable, and could not be effaced by any other sign. A place where a person had been struck by lightning was thenceforth devoted to the gods and protected from desecration by a fence.

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[1] Creuzer, 'Symbolik,' zweiter Theil, zweite Ausgabe, p. 20.

[2] Many different kinds of lightning were distinguished by the Etruscan priests; for instance, *fulmina postulatoria*, which required a sacrifice that had either been neglected or not properly performed; *monitoria*, warning to avoid some place or action; *fallacia*, deceiving by an appearance of good and bringing evil; *deprecatoria*, bringing apparent danger without its reality; *regalia*, striking some chief building of a free city, and consequently of great public significance. A lightning which blackened the objects it struck was considered of evil import, but a lightning which merely touched an object without producing any change of colour was eminently fortunate. Lightnings which struck from left to right were excellent signs.

Among the Romans, who derived a great part of their superstitions from Etruria, the lightning preserved its full augurial significance. The Curtian lake and the Ruminal fig-tree in the Forum, having been touched by lightning, were held sacred, and the memory of the accident was preserved by a puteal or altar erected over the cavity that was said to have been made by the thunderbolt. Persons killed by lightning were wrapped up in a white garment and buried on the spot where the fatal accident occurred. Their bodies were supposed to be incorruptible, and a stroke not fatal conferred a perpetual dignity upon the man thus distinguished by heaven. That Mithridates, the mortal enemy of Rome, had been slightly wounded on the forehead by lightning while still a child, and later in life escaped unhurt while his sword, that was lying near him in his sleep, was consumed by the celestial fire, served no doubt to increase the terror of his name among his superstitious enemies. And Quintus Julius Eburnus, who was made consul in the year 116 before our era, probably owed his dignity to his having been distinguished in a similar manner by the gods.

When a tomb was struck by lightning this also was considered as a special sign of divine favour; and among the sepulchres of persons thus honoured after death, Suetonius mentions that of Julia, the daughter of Cæsar, and Plutarch those of Lycurgus, the Spartan legislator, and of the poet Euripides.

In his beautiful stanza,[1] on the bust of Ariosto which had been struck by lightning on the poet's tomb at Ferrara, Lord Byron alludes to this ancient superstition.

The lightning rent from Ariosto's bust
The iron crown of laurel's mimick'd leaves;
Nor was the ominous element unjust,
For the true laurel wreath which glory weaves

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[1] 'Childe Harold,' Canto IV., stanza 41.

Is of the tree no bolt of thunder cleaves,
And the false semblance but disgraced his brow;
Yet still, if fondly superstition grieves,
Know, that the lightning sanctifies below
Whate'er it strikes;—yon head is doubly sacred now.

The ancients, who paid so much attention to the ominous significance of lightning, were completely ignorant of its nature. Most of their philosophers considered it to be a kind of spirit, suddenly inflaming itself in the air, and formed by the *dry exhalations* of the earth, which, on mixing with the atmosphere, were also supposed to produce the winds; while the *moist exhalations* gave birth to clouds, fogs, and rain. Others again, considering that lightning issues from the midst of humid vapours, supposed it to result from the transformation of the dense and moist air of the clouds, warmed and subtilised by their motion. The mutual friction of the clouds or their violent concussion was supposed to be the cause of the eruption or inflammation of the spirit, in the same manner as a spark is produced by striking two stones or two pieces of iron against each other.

Some philosophers finally derived lightning from the upper ethereal regions. According to Empedocles it was composed of solar rays held captive in the clouds; and Pliny adopted the bold Babylonian hypothesis, according to which some lightnings proceed from the three superior planets—Saturn, Jupiter, and Mars—and merely traverse the clouds.

All these theories, however specious the reasonings upon which they were founded, were, of course, mere idle speculations, for thunder and lightning are the effects of a vast explosion of electricity accumulated in the atmosphere; and of the powers of electricity, though it had already revealed some of its mysterious force to the ancients when they rubbed a piece of amber, nothing was known before the last half of the seventeenth century. About the year 1673 Otto von Guericke, the inventor of the air-pump, elicited the first luminous sparks from a very imperfect electrical apparatus; and about the same time Dr. Wall produced more lively and noisy sparks by the friction of a large cylinder of resin. In a memoir inserted in the 'Philosophical Transactions,' he boldly conjectured their resemblance to thunder and lightning; but the Abbé Nollet appears to have formed the first distinct idea of their similitude, as he expresses himself on the subject in the following remarkable manner:—

'If anyone should take upon himself to prove from a well-connected comparison of phenomena, that thunder is in the hands of Nature what electricity is in ours, that the wonders which we now exhibit at our pleasure are little imitations of those great effects that frighten us, and that the whole depends upon the same mechanism, I avow that this idea, if it was well supported, would give me a great deal of pleasure, and in support of it how many specious reasons present themselves to a man who is well acquainted with electricity! The universality of the electric matter, the readiness of its action, its inflammability and its activity, its giving fire to other bodies, its property of striking externally and internally even to their smallest parts—all these points of analogy, which I have been some time meditating, begin to make me believe that, by taking electricity for the model, one might form to oneself, in respect to thunder and lightning, more perfect and more probable ideas than have hitherto been offered.'[1]

The immortal honour of having afforded the first experimental proofs of the truths of this hypothesis belongs to Dr. Franklin, who truly realised the fable of Prometheus in bringing down fire from heaven. Reasoning from the many particulars in which the external phenomena of lightning and electricity agree, such as their striking the highest and most pointed objects in their way, their taking the readiest and best conductors, their setting fire to inflammable bodies, their fusing metals, their rending some bodies, their paralysing or destroying animal life, he conceived the bold idea of ascertaining the truth of this doctrine[2] by actually drawing down the lightning from the clouds. As pointed conductors attract the electrical fluid more easily than those of any other form, he conceived that pointed rods of iron fixed in the air, when the atmosphere was loaded with lightning, might draw from it the matter of thunderbolts without noise or danger into the body of the earth. His account of this supposition is given by himself in the following words:—'The electric fluid is attracted by points. We do not know whether this property be in lightning; but since they agree in all the particulars in which we can already compare them, it is not improbable that they agree likewise in this. Let the experiment be made.'

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[1] 'Leçons de Physique.'

[2] The first account of Franklin's theories appeared in the form of 'Letters to Mr. Collinson,' in England (1749) who published them in a separate volume.

His original plan for putting this theory to a decisive test was to erect on some high tower a sentry-box from which should rise a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this would, he conceived, impart to it a portion of their electricity, which would be rendered evident to the senses by sparks being emitted when a key, the knuckle, or other conductor, was presented to it. But as Philadelphia in his time afforded no opportunity of trying an experiment of this kind, he lost some years waiting for the construction of a spire, until at last the lucky thought occurred to him that it might be made in an easier manner by means of a common kite. He prepared one by fastening two cross-sticks to a silk handkerchief, which could not suffer so much from the rain as paper. To the upright stick was affixed an iron point. The string was as usual of hemp, except the lower end, which was of silk, a bad conductor of electricity. Where the hempen string terminated a key was fastened. Provided with this simple apparatus he took the opportunity of the first approaching thunderstorm to walk into a field, where there was a shed proper for his purpose. But dreading the ridicule which too generally for the interests of science attaches itself to unsuccessful experiments in philosophy, he communicated his intention to no one but his son, who assisted him in raising the kite. A considerable time elapsed before there was any appearance of success. One very promising cloud had passed over the kite without any effect, when just as he was beginning to despair, he observed some loose threads of the hempen string to stand erect and avoid one another, just as if they had been suspended by the conductor of a common electrical machine. He now presented his knuckle to the key, and received a strong spark. Others succeeded, even before the string was wet, but when the rain began to descend the electric fire descended so copiously that a phial was charged, and all the experiments made which were then usually performed with electricity. How exquisite must his sensations have been when the success of his experiment showed him that he had discovered one of the grand secrets of Nature, and insured to himself a distinguished place among the illustrious discoverers whose genius has opened new fields of knowledge to man! Yet in his case exquisite joy seems to have been tinged with melancholy, for we are told that when he saw the fibres of the string erect themselves he uttered a deep sigh, and wished that moment to be his last, feeling that he had now immortalised his name.

It by no means detracts from Dr. Franklin's glory that about a month before he made his ever-memorable experiments with the kite, the truth of his theory had already been verified in France, where the learned had received it with delight. Two gentlemen, Messrs. D'Alibard and De Lor, were particularly eager in following the track which Franklin had pointed out, and erected apparatus for that purpose—the former at Mary la Ville, and the latter at his house in the Estrapade at Paris, some of the highest ground in that capital. D'Alibard's machine first showed signs of electricity. On May 10, 1752, a thunder cloud passed over it, in the absence of M. D'Alibard, and a number of sparks were drawn from it by one Coifier, a joiner, with whom he had left directions how to proceed. On May 18, M. De Lor proved equally successful with the apparatus erected at his house. These philosophers stimulated those of other parts of Europe to repeat the experiment, amongst whom none signalised themselves more than the celebrated Father Beccaria, of Turin, who soon discovered that signs of atmospherical electricity might be obtained not only during a thunderstorm but almost at all times and in every kind of weather. Even the cold regions of Russia were penetrated by the ardour for discovery. Professor Richman, of St. Petersburg, bade fair to add much to the stock of knowledge on this subject when an unfortunate flash from his conductor put an end to his existence.

The majestic phenomenon of the thunderstorm, which, according to the degree of intellectual culture attained by man, has thus in all ages influenced his religious feelings or excited his spirit of enquiry, and, as his mind is 'tuned,' fills it with fear or admiration, is always caused by the rapid mixture of air currents of an unequal temperature, and a consequent sudden condensation of a large quantity of aqueous vapour, for it is only under these circumstances that a cloud attains an electrical tension of sufficient strength for the production of lightning. When clouds and rain gradually form, the small quantity of electricity disengaged during the process loses itself imperceptibly in the moist atmosphere. The electrical discharges of a thunderstorm are, therefore, only secondary phenomena—not causes, but effects.

THUNDERSTORM.

Most thunderstorms, particularly those which take place in the equatorial regions and in summer, are occasioned by the cooling of ascending warm air-streams rising from the heated earth. Thunderstorms of this description are very frequent in deep sultry valleys inclosed on all sides by mountains, where the ascending current meets a cold wind on its emerging into free space; and also in broad open valleys, when the heated air, impelled by a strong wind, is forced to rise along the flank of a steep mountain.

During every volcanic eruption the ascending column of steam produces, by its condensation in the higher regions of the atmosphere, a strong electrical tension, which discharges itself with terrific explosions. Thunderstorms caused by an ascending air-stream are generally of short duration; the clouds soon disperse, and the sun soon shines again in the blue sky. But as the heat which gave rise to the ascending air-current still continues, they often reappear at about the same time during several consecutive days. Our western thunderstorms, on the contrary, generally bring us a continuance of cold and rainy weather. They are caused by the influx of the polar air-stream, which, mingling with the warm and damp equatorial current, produces a sudden precipitation of water and electrical discharge. Meanwhile the barometer rises, and the temperature becomes colder. A reaction often takes place, when the warm current drives back its adversary for a time. When these thunderstorms occur in winter they are accompanied by heavy snowfalls,

VOLCANIC THUNDERSTORM.

(Lightning from dense cloud over Volcano in eruption.)

and followed by a severe cold, as the north-east wind now gains the mastery.

The sudden victory of the equatorial stream over the polar current likewise occasions thunderstorms. These are distinguished from the former by an increase of temperature and a fall of the barometer. They take place at a considerable altitude, and advance but slowly, as the polar stream, predominating in the lower regions of the atmosphere, resists their progress, and only gradually gives way.

When thunderstorms that have been formed over a plain strike in their progress against a wooded hill they often remain stationary for some time, and then deviate from their original direction. Sometimes they are divided or split into two by one of these barriers, and then the separated storms either continue to advance in divergent directions, or unite again behind the barrier when the latter is but of inconsiderable extent.

Before the lightning begins to flash the storm announces its approach by a peculiar cloud-formation. The atmosphere loses its clearness; the temperature, if it takes place in the warmer part of the year, becomes oppressively sultry. Then thick clouds begin to gather, at first singly, but rapidly increasing in size until they soon cover the greater part of the sky. Their dark colour, sometimes passing into a deep gray black, and here and there interspersed with smaller and lighter clouds, gives the troubled sky a remarkably dismal appearance, which ominously announces that a formidable atmospherical crisis is preparing. 'When,' says Arago, 'one sees suddenly, during calm weather, on any point of the horizon, thick clouds with curved and sharp outlines, resembling mountain cupolas covered with snow; when these clouds seem to expand, and, diminishing in number, increase in size, but at the same time remain fixed to their original bases, and when the broken outlines melt into a single mass, the approach of a thunderstorm may be confidently expected.' At first an absolute calm still reigns in the atmosphere, and this tranquillity, which forms so striking a contrast with the menacing aspect of the clouds, increases the anxiety with which so many persons look forward to the explosion of a thunderstorm. Suddenly the wind rises in violent gusts, the trees bend their crowns, the corn-field waves like an agitated sea, the clouds glide rapidly through the sky, thick columns of dust are swept upwards from the parched fields, single heavy drops fall upon the thirsty earth, and soon torrents of rain or showers of hail descend, under the well-known electrical phenomena of thunder and lightning.

> From the damp earth impervious vapours rise,
> Increase the darkness, and involve the skies.
> At once the rushing winds, with roaring sound,
> Burst from th' Eolian caves and rend the ground,
> With equal rage their airy quarrel try,
> And win by turns the kingdom of the sky.
> But with a thicker night black Auster shrouds
> The heavens, and drives on heaps the rolling clouds,
> From whose dark womb a rattling tempest pours
> Which the cold north congeals to haily showers.
> From pole to pole the thunder roars aloud,
> And broken lightnings flash from every cloud;
> Now smokes with showers the misty mountain ground,
> And floated fields lie undistinguish'd round.
> Where late was dust, now rapid torrents play,
> Rush through the mounds, and bear the dams away;
> Old limbs of trees, from crackling forests torn,
> Are whirl'd in air and on the winds are borne.
>
> Pope's '*Thebais.*'

In a letter to the editor of the 'New York Tribune' (Lancaster, Pennsylvania, February 1857), Mr. J. Wise, the celebrated American aeronaut, gives an interesting account of the physical aspect of thunderstorms as viewed in a balloon from above the clouds, from their sides in mid-air, and from the middle of their cauldrons.

'A storm viewed from above the clouds has the appearance of ebullition. The upper surface of the cloud is bulged upward and outward, and when viewed from a point where the atmosphere is clear around and above, has the resemblance of a vast sea of snow boiling and upheaving from internal convulsion. Immediately above the storm the air is not so cold as in a place where there is no cloud nor storm beneath. The falling of the rain can be heard above the cloud, making a noise like a waterfall over a precipice. The thunder heard above the cloud is not loud, and the flashes of lightning appear like streaks of intensely white fire on a surface of white vapour.

'A side view of a storm, observed when it is a mile or two off, and somewhat lower than the point of observation, presents in form the shape of an hour-glass; and the picture of a waterspout also gives a good outline of its shape. In this well-defined form it moves along over the earth. When the storm is so small that its whole bulk can be embraced at a single glance, which can be done when the balloon is several miles off, and a little more elevated than the meteor, it looks as though it were trailing its lower base along on the surface of the earth, and it has an individuality which cannot be recognised when viewed from the ground. Although the storm is being moved along by the same current of wind that is drifting along the observer, it will be deflected from that course by its encountering a mountain ridge, just in proportion to the amount of lateral force or obstruction it sustains in such cases, and then the observer in a balloon may continue onward, while the storm may be moving off at right angles with his route. These lateral views of storms are very grand and imposing as they rush along before an elevated observer. A grand army of flying artillery at full gallop, in all the panoply of war, could not produce so imposing a sight; over city and forest, river and plain, it goes with undaunted march.'

A storm viewed from within its cauldron—that is, from within its vortex, where the cloud vapour is driving upwards to where it spreads out—is rather a terrible thing; but the very fact of being caught up in the midst of one of Nature's laboratory furnaces makes one feel resigned, though Mr. Wise assures us he would not like to enter one again for observation, until science had given him a positive assurance against danger. The one now to be described was the result of a trip in the midst of a local storm of so limited dimensions as to have no electrical explosions during his passage of nineteen minutes within its bosom. This storm originated nearly over the town of Carlisle, Pennsylvania, on June 17, 1843. The nucleus cloud above was just spreading out as he entered the vortex unsuspectingly. He was hurled into it so quickly, that he had no opportunity of viewing its surroundings outside, so that his observations were confined to its internal action. On entering it, the motion of the air swung the balloon to and fro, as also around in a circle, and a dismal howling noise accompanied this unpleasant and sickening motion; and in a few minutes thereafter was heard the falling of heavy rain below, resembling in sound a cataract. The colour of the cloud internally was of a milky hue, somewhat like a dense body of steam in the open air, and the cold was so sharp that his beard became bushy with hoar-frost. As there were no electrical explosions in the storm during his incarceration, it might have been borne comfortably enough but for the sickness occasioned by the agitated air-storm. Still, he could hear and see, and even smell everything close by and around. Little pellets of snow (with an icy nucleus when broken) were pattering profusely around him in promiscuous and confused disorder, and slight blasts of wind seemed occasionally to penetrate the cloud laterally, notwithstanding there was an upmoving column of wind all the while. This upmoving stream would carry the balloon up to a point in the upper cloud, where its force was expended by the outspreading of its vapour, whence the balloon would be thrown outward, fall down some distance, then be drawn into the vortex again, to be carried upward, to perform the same revolution, until the aeronaut had gone through the cold furnace seven or eight times. All this time the smell of ozone was perceptible, and he was perspiring profusely from some cause unknown to him, unless it was from undue excitement. The last time of descent in this cloud brought the balloon through its base, where, instead of the pellets of snow, there was encountered a drenching rain, with which the balloon came down into a clear field, and the storm passed on.

Thunderstorms viewed from the earth have not the characteristic shapes lineated to the eye of the observer, when viewed sidewise from above; neither does one discover the two plates of clouds joined in conic sections. The upper cloud can be seen rolling outward, and black clouds below centering inward, but the whole seems to be nearly blended in one solid mass. By close observation and practice it will, however, soon be deduced that there are two plates of clouds, even as viewed from the earth.

Thunderstorms rage more violently as they pass over forests or moist places, and were it not for the deposition of rain as they pass along their path would exhibit a parched trail.

Thunderstorms are deflected in their course, as well as retarded in their movement, by friction on the earth. Ascending from the earth with a balloon in the rear of a storm, and mounting up a thousand feet above it, the balloon will soon override the storm, and may descend in advance of it.

Lightning, the electrical fire bursting forth from the thunder-cloud, appears under various forms; generally in angular or zig-zag flashes, with sharply defined borders, and almost without any apparent breadth, or in wide sheets, illuminating enormous spaces with indistinct outlines, like a sea of flame, or more rarely, in the shape of a ball of fire. These globular lightnings are remarkable for the slowness with which they generally move. While, as Arago's optical experiments have proved, a flash of sheet or forked lightning does not even last the thousandth part of a second, they descend so slowly from the cloud that the eye can easily follow them in their progress, and calculate their duration. M. Colon, Vice-president of the Parisian Geological Society,

GLOBE OF FIRE DESCENDING INTO A ROOM.

saw one of these singular meteors leisurely gliding downwards along the bark of a poplar. It took at least five or six minutes to reach the base of the tree, as if unable to overcome the resistance of the air; but on touching the ground it rebounded with a wonderful rapidity, and disappeared without exploding.

Frequently, globe lightning seems to approach the earth with a certain repugnance, as if it were unwilling to quit its aerial birthplace. The French admiral Duperrey, relates that he once saw, in the Indian Archipelago, a tremendous spherical cloud, which sent forth thunder and lightning on all sides, and which finally disappeared, without having ceased to remain at some distance from the earth.

One day the inhabitants of Northampton saw a fiery globe passing over their heads. It made a terrible hissing noise, as if though unwilling or incapable to strike them, it at least wanted to enjoy their terror.

When these astonishing meteors touch the ground, their movements are extremely capricious and irregular. They stand still, as if deliberating where to go next; they then roll on, or spring upward like an elastic ball, or divide into smaller globes. Frequently, at the end of their march, they explode with a terrible noise, and scattering zig-zag flashes in all directions.

The colours of lightning are various—a pale straw colour, a bright yellow, and different shades of blue, are the most ordinary tints. Forked lightning is the most dazzling, sheet lightning fainter, and frequently of a somewhat reddish glare, as may distinctly be seen when both kinds of lightning appear simultaneously. The colour of globe lightning varies from a dull white to a fiery red. The explosion of lightning is always attended with the evolution of heat, which is sometimes so considerable as not only to set fire to matters of a combustible nature, such as wood, but to melt and consume, in an instant, the most refractory substances.

Many remarkable instances are related of the power of lightning in fusing metals. The great mast of the packet-boat, the 'New York,' was surmounted by a long rod of iron, terminating in a point; a chain about 120 feet long was attached to this rod, and served as an electrical conductor from the top of the mast to the ocean. The lightning struck the rod, and the chain being too weak to conduct the electrical discharge, was entirely volatilised, though it weighed more than nine pounds. In 1759, the lightning struck the massive conductor of a chapel in the island of La Martinique; the rod was of considerable weight and circumference, yet in one single instant the lightning reduced it to the dimensions of a wire. Even solid stone is melted and fused by the gigantic power of lightning. Saussure saw traces of fusion on the top of Mont Blanc, and Humboldt and Bonpland found the surface of about two square feet of rock vitrified by lightning, on the summit of the volcano of Toluco.

But the vitrified tubes which are formed by lightning entering loose sand are the most striking instances of the enormous temperature it is able to evolve. In a broad band of sand-hillocks near Maldonado, at the mouth of the La Plata, Mr. Darwin found a group of lightning tubes. The sand-hillocks, not being protected by vegetation, are constantly changing their position. From this cause the tubes projected above the surface, and numerous fragments lying near showed that they had formerly been buried to a greater depth. Four sets entered the sand perpendicularly; by working with his hands, Mr. Darwin traced one of them two feet deep, and some fragments, which evidently had belonged to the same tube, when added to the other part, measured five feet three inches. The diameter of the whole tube was nearly equal, and hence it is probable that originally it extended to a much greater depth. These dimensions are, however, small compared to those of the tubes found at Drigg, in Cumberland, one of which was traced to a depth of not less than thirty feet. The internal surface of the tubes was completely vitrified, glossy, and smooth; the thickness of their wall varied from a thirtieth to a tenth of an inch. The tubes were generally compressed, and had deep longitudinal furrows, evidently caused by the compression from the surrounding loose sand acting while the tube was still softened from the effects of the intense heat. Their circumference was about two inches, but in some cylindrical and unfurrowed fragments as much as four. Judging from these, the measure or bore of the lightning must have been about an inch and a quarter. Mr. Darwin mentions [1] that at Paris, Hachette and Beudant succeeded in making tubes in most respects similar to these fulgurites, by passing very strong shocks of galvanism from the most powerful battery in Paris through finely-powdered glass, but failed both with powdered felspar and quartz. The largest tube they could produce was, however, not an inch long, and not one-fiftieth part of an inch broad. These diminutive effects, produced by a battery of uncommon power on a substance of such easy fusibility as glass, are well calculated to raise our astonishment at the force of a shock of lightning, which is able to fuse tubes thirty feet long in a material so extraordinarily refractory as quartz.

Another remarkable circumstance in the history of the fulgurites (which were first noticed in the year 1711 by a Silesian clergyman, but whose origin was first traced in 1805 by Dr. Hentzen, near Paderborn), is the number of tubes found within limited spaces. At Drigg, within an area of fifteen yards, three were observed, and the same number occurred in Germany, in a case described by Mr. Ribbentrop.[2] As it does not appear probable that the tubes are produced by successive distinct shocks, we must believe that the lightning, shortly before entering the ground, divides itself into separate branches.

When the lightning, in its course, meets with any obstruction, as in passing through a body which is an imperfect conductor, it overcomes this obstruction by forcing a passage through the resisting body. Hence, we commonly find large beams shattered, and stones and bricks either driven from their places or split and perforated in an unequal manner. Frequently the lightning will forsake one conducting body, as the handle of a bell-wire, and strike through the wall of the room, attracted by some conductor either of greater power or larger dimensions, such as a kitchen grate on the other side. This effect of lightning is exactly similar to the perforation and rending of bodies by electricity, and is undoubtedly owing to the sudden expansion of the air or moisture contained within the pores of the resisting body.

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[1] 'Journal of Researches.'

[2] Ribbentrop, 'Ueber Blitzröhren,' 1830.

Lightning shows its terrific power not only by the facility with which it cleaves rocks or fuses the hardest stones, but also by the removal of the heaviest weights. On June 21, 1723, the lightning struck a tree in the forest of Nemours. The two pieces into which the trunk was severed were five metres and seven metres long. Four men would have been unable to move the first piece, which the lightning flung to a distance of thirty paces; the second had been cast to a distance of fifteen feet in the opposite direction, although its weight would have defied the efforts of eight men to move it. When, in 1762, the lightning destroyed the steeple of Breag, in the county of Cornwall, stones weighing 150 lbs. were flung to a distance of 180 feet. At Funzie, in Fetlar (Shetland Islands), about the middle of last century, a rock of mica schist, 105 feet long, ten feet broad, and in some places four feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large and several smaller fragments. One of these, twenty-six feet long, ten feet broad, and four feet thick, was simply turned over. The second, which was twenty-eight feet long, seventeen broad, and five feet in thickness, was hurled across a high point to the distance of fifty yards; another broken mass, about forty feet long, was thrown still farther, but in the same direction, quite into the sea.[1]

Metals are, as it is known, the best conductors of lightning, and after them all wet or moist objects. Thus, when lightning strikes a tree, it makes its way frequently in a spiral direction in the interval filled with sap, between the wood and the bark, not seldom peeling or tearing off the latter. Steam and smoke ascending during a thunderstorm can serve as conductors to lightning. It is a well ascertained fact that it not seldom strikes into smoking chimneys, down which it seems to be conducted by the soot. Men and animals are likewise good conductors, particularly when they are prominent objects in the open country.

Lightning, when sufficiently intense, takes the shortest way to the earth; it sometimes springs from a better to a worse conductor, if the latter supplies it with a more direct communication. Although it generally strikes downward, the lightning flash sometimes darts sideways, or even upwards, when the cloud hangs on the side of a mountain. On May 1, 1700, as Dr. Melnoschrigg was on his way to the chapel, on the summit of Mount Saint Ursula, in Styria, he saw black clouds forming about the middle part of the mountain, which soon afterwards discharged themselves in a terrible thunderstorm. Above the top of the mountain the sky was perfectly serene and sunny, so that the chapel might have been supposed a perfectly safe asylum, yet the lightning, striking upwards, killed seven persons close to the doctor, who remained unhurt.

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[1] Sir C. Lyell's 'Principles of Geology,' vol i. p. 503.

The thundering sound which attends the lightning-flash varies according to the distance from which it is heard, and the nature of the country where the storm takes place. At some distance it is generally a hoarse grumbling noise, which appears to extend through a considerable part of the atmosphere, and gradually dies away. If it be heard very near, the crash is instantaneous, and exactly similar to the explosion of a cannon when we are very near it at the time of its being fired.

When the explosion is very near, the snap begins with great smartness, and for some time resembles the violent tearing of a piece of strong silk, but it becomes more mellow as it proceeds to a greater distance. The explosion of thunder differs from the sound which is produced by the discharge of an electrical battery, not only in its degree of loudness, but in its nature; it is a long-continued, rumbling, unequable noise. The long-continued roar of thunder is certainly owing to the commencement and termination of the explosion reaching our ears at different periods of time, and the unequally loud rumbling noise is owing to the different parts of the explosion striking the ear in a different manner.

In a level and low country, where there is no diversity of reverberating objects, and particularly at sea, the series of explosions gradually grows fainter as the length of time increases. But in a mountainous country, where the thunder awakens a thousand echoes, it is not bound to regularity, and there is a long and broken succession of claps, frequently following each other for some time with fitful and unabated energy. Here, therefore, is the scene where the grand phenomenon of the storm shows itself in all its awful sublimity :—

> Far along,
> From peak to peak, the rattling crags among
> Leaps the live thunder! Not from one lone cloud,
> But every mountain now hath found a tongue,
> And Jura answers, through her misty shroud,
> Back to the joyous Alps, who call to her aloud!
>
> And this is in the night :—Most glorious night!
> Thou wert not sent for slumber! let me be
> A sharer in thy fierce and far delight,—
> A portion of the tempest and of thee!
> How the lit lake shines, a phosphoric sea,
> And the big rain comes dancing to the earth!
> And now again 'tis black,—and now, the glee
> Of the loud hills shakes with its mountain-mirth,
> As if they did rejoice o'er a young earthquake's birth.
>
> '*Childe Harold.*'

The distance of a thunderstroke may easily be ascertained by observing the flash and counting, by means of a watch with a *seconds' hand*, the number of seconds which elapse between its appearance and the commencement of the roar. As sound travels through air at the rate of about 1,100 feet in a second, a simple multiplication of the number by that of the seconds which have been counted, gives us with sufficient accuracy the distance of the stroke from the place of observation.

The greatest distance at which thunder can be heard seems to be no more than six leagues. On January 25, 1757, the lightning struck the church steeple of Lostwithiel, in Cornwall, with a terrific roar, and destroyed it almost completely. Mr. Smeaton, the celebrated engineer, was about thirty miles distant at the time, and did not hear the slightest noise. Muschenbrock relates that it sometimes thunders very loudly in the Hague without any noise being heard in Leyden, though only four leagues distant.

This is the more astonishing when we hear how enormously far the roar of artillery is propagated through the air. The cannonade of sieges and great battles can be distinctly heard at thirty leagues' distance and more. During the siege of Paris the roar of the Krupp cannons was heard during the nights of bombardment at Dieppe, thirty-five leagues from the capital. The cannonade of March 30, 1814, which preceded the entrance of the allies into Paris, was heard at Casson in Normandy, at a distance of forty-four leagues; and Arago informs us that the cannon of Waterloo carried its sound as far as Creil, which is fifty leagues distant from the field of battle.

Thunder clouds frequently form at a very considerable height above the level of the sea. On November 15, 1869, Dr. Bergsman, while looking up to the zenith in order to observe the direction of the clouds, saw right over his head a strong flash of lightning dart from west to east, and heard eighteen seconds later the beginning of the thunder. Thus the height of the lightning was at least 18,000 feet. I have already mentioned that thunderstorms have left their traces above the snow-fields of the Andes, and have been seen high over the summit of Mont Blanc and the other monarchs of the Alps. Sometimes, however, the clouds which give birth to lightning are remarkably low. On August 26, 1827, a thunderstorm discharged itself during the vesper service over the Convent of Admont in Austria, and killed two young priests in the choir of the church. The cloud from which the fatal stroke proceeded was only eight metres thick, and its vertical distance from the ground no more than twenty-eight metres. The convent lies in the valley. A castle situated on the declivity of the hill, at a height of 117 metres, was inhabited at the time by a keeper and his wife. During the whole duration of the thunderstorm these two persons saw the cross of the convent steeple thirty-six metres above the cloud, the basis of which reached a window twenty-eight metres above the ground.

On June 15, 1826, a remarkable thunderstorm took place at Grätz, the capital of Styria. In less than an hour the lightning struck nine times. The town is situated at the foot and on the declivity of the Schlossberg, which is 490 metres high. During the storm the fortress, situated at the top of the mountain, was completely unclouded, the sky above perfectly serene and blue. It afterwards was found by accurate measurements that the cloud which produced such destructive effects had only been thirty-six metres thick.

Although most thunderstorms pass over our heads without doing any serious damage, for, as Seneca[1] remarked, 'Lightning, which brings fear to everybody, brings peril only to a very few,' yet not a year passes in which the fire of heaven does not prove destructive to human life. According to statistical accounts, about ninety persons are annually killed by lightning in France; and Arago believes this number to be underrated, as corpses are not seldom found in the fields or woods whose deaths may have been caused by lightning. Deaths from lightning are more frequent in the country than in towns, but in the latter a greater number of victims is sometimes struck at once. In the year 1793[2] one of the most destructive thunderstorms perhaps on record happened at Buenos Ayres; thirty-seven places within the city were struck by lightning, and nineteen people killed.

On July 26, 1759, the lightning struck the theatre at Feltre, in Lombardy, and killed a great number of spectators. A similar catastrophe took place on March 20, 1784, in the theatre at Mantua. Among the four hundred spectators who had assembled for amusement, and little expected such an interlude, two were killed and ten wounded. The lightning melted, moreover, watch-keys, earrings, and split diamonds, without otherwise injuring their possessors. On June 11, 1819, the lightning struck during divine service into the church of Château Neuf les Moutiers, in the Department of Les Basses Alpes, killed nine persons and wounded, more or less severely, eighty-two.

During the thunderstorms which raged over England in June and July, 1872, a great number of persons were killed by lightning in different parts of the country. Among the deaths which occurred from this cause on June 18, the newspapers mention—A young gentleman killed in a field near Mowthorps, Yorkshire; a young fisherwoman at Musselburg, near Edinburgh, while collecting bait; at Newcastle, a woman in Scott's wood-road, and two sailors on board a vessel coming up the Tyne; at Nottingham, a pensioner named Carter; a woman and child at Walsall; an Irish labourer at York; a child near Manchester. Thus ten fatal accidents are known to have taken place on that single day, and probably the above list is far from being complete.

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[1] 'De Clementia,' i. 8, § 4.

[2] 'Azara's Voyage,' vol. i. p. 36.

When catastrophes such as these appear grouped together, they no doubt present an alarming spectacle; but when we consider that they are disseminated over a vast extent of country, peopled by many millions of inhabitants, and that probably among 10,000 deaths there is on an average scarcely one from lightning, they by no means justify the excessive fears which so frequently agitate nervous people during a thunderstorm.

Arago remarks that more persons are killed in Paris by the fall of a tile from a roof, or of a flower-pot from a window, than by lightning; and there can be no doubt that in London the danger is far greater of being overrun by a cab than of being struck by the electrical flash of a thunderstorm. In the 'London Medical Record' we find it mentioned that during the year 1870 there were in the whole country 202 deaths from lightning stroke. The total number of deaths from all causes was nearly 500,000. Thus there were 2,437 deaths from other causes to one death from lightning, and there were 190,883 persons living to every one killed by this cause. The deaths from sunstroke were almost twice as many.

'While I am writing this,' says Lichtenberg, in a witty article on the 'Fear of Lightning,'[1] 'symptoms of dysentery are showing themselves with us in Göttingen. Six persons are said to have died of this complaint—that is more than twice as many in a few days as the lightning has killed in our town in more than half a century—and yet the public seems remarkably easy on the subject. I do not even find that the cheapest *dysentery-conductors* have been resorted to. People still go about in light clothing, although the wind is already blowing over the stubble, and I have even perceived within the last few days that some persons sleep with open windows, which are very carefully closed during a thunderstorm, and yet there is not a single instance known that lightning has ever made its way through an open window, while dysentery very easily strikes into a bedroom, particularly when, after a warm day, it makes its appearance in the company of rain and a cool wind. Is not this singular? How would people conduct themselves in these days if the dysentery was to rise above the horizon in the form of a low black cloud, changing day into twilight, and whenever it selected a victim, explode with a violent thunderclap, which made the house shake? I believe there would be no end of singing and praying. And yet this storm is now impending over our heads—but without thunderclaps and black clouds, which are, after all, only accessories—and we go about our affairs as if nothing were happening.'

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[1] 'Göttingenscher Taschen-Kalender.'

It has been observed that lightning seems to have a marked predilection for striking certain persons. Thus, Father Bosco, of Turin, was thrice struck during his residence in three different places; Mrs. Hain, an American lady, having been wounded by lightning in her left foot in the year 1840, was again wounded in the same limb fifteen years later; and, from what we have seen at the beginning of the chapter, the famous Mithridates was also one of these privileged persons.

'In two situations completely similar,' says Arago, 'one man, through the nature of his constitution, runs more danger than another. There are persons who suddenly stop the communication of electricity, even when occupying the second place in the chain, and do not feel the shock. These exceptional persons are non-conductors of the fulminating power, and must therefore be ranged among the non-conducting bodies which the lightning respects, or at least strikes very rarely.

'Such notable differences can, however, not exist without many intermediate grades, and every degree of conductibility corresponds during a thunderstorm with an analogous degree of danger. The man who is as good a conductor as metal will be struck as often as a metal, while the man who interrupts the communication in the chain will have no more to fear from lightning than if he were made of glass or resin. Between these extreme limits individuals will be found which the lightning will strike as it does wood or stone. Thus in a thunderstorm all does not depend upon the spot occupied by a man, but his physical constitution has also a certain influence.'

It has likewise been remarked that man is less liable to be struck by lightning than animals. In 1715 the lightning fell into the Abbey of Noirmoutiers, near Tours, where it killed twenty-two horses without doing any other harm to the 150 monks of the convent whom it visited in the refectory, than overturning the 150 bottles which contained their rations of wine. On June 1, 1855, the lightning fell upon a flock of sheep in the parish of St. Leger la Montagne (Haute Vienne): seventy-eight sheep and two dogs were immediately killed, but the woman who guarded the flock was but slightly hurt. Many similar instances might be cited where a great number of domestic animals were struck dead by lightning, while their shepherds or drovers either escaped altogether or recovered from the shock.

Both in France and other countries the number of men killed by lightning is more than double that of the women, a difference probably owing in a great measure to the circumstance that accidents from lightning are most common in the fields and open country, where, particularly in bad weather, the number of men engaged in some occupation far exceeds that of the weaker sex, which is more generally busy with household work. It has, however, been observed that in a group equally composed of both sexes, lightning principally strikes the men, whether it be on account of their higher stature, or that the female dress affords better protection, or that the conductibility of the electric fluid is different in the two sexes. Children are rarely killed.

Buildings are more frequently destroyed or injured by lightning than men. In the single night of April 24–25, 1718, the lightning struck twenty-four steeples on the coast of Brittany.

In 1759, on July 27, the lightning burnt all the wood of the roof of Strasburg cathedral. In the month of October of the same year it struck the tower of this magnificent edifice, and so completely demolished one of the pillars which support the top part of the tower that the thought was seriously entertained of pulling it down. The cost of repairing the damage amounted to more than 300,000 francs.

After the French, under Marshal Melac (whose memory is still kept alive on the former theatre of his exploits by his name being frequently bestowed on members of the canine race), had so effectually destroyed the superb Castle of Heidelberg, that if the hordes of Napoleon III. had been able to effect their projected raid into Germany they might still have found in those splendid ruins '*the glorious traces of their ancestors*,' the Elector Charles Theodore ordered part of it to be rebuilt, with the intention of once more fixing his residence in the old burg of his fathers. But as he was about to effect his purpose the new palace was struck by lightning, and fire consumed the last inhabitable parts of the ancient seat of princes.

Most terrible devastations have been caused by lightning striking into powder magazines. On August 18, 1769, it fell into the tower of St. Nazaire at Brescia. In a subterranean vault below the tower lay an enormous quantity of powder, which immediately exploded. The sixth part of all the buildings of the large and populous city were destroyed, and none remained undamaged. Three thousand persons lost their lives. The tower blew up, and fell down again in a shower of stones, some of which flew to an enormous distance. The damage amounted to 16,000,000 francs.

On June 26, 1807, the lightning struck in the fortress of Luxemburg a powder magazine which contained 30,000 pounds of powder. Thirty persons lost their lives, and more than 200 were severely wounded. The lower town was a heap of ruins. Large stones of the tower were hurled to the distance of about a league.

On November 6, 1856, the lightning struck the church of St. John in the island of Rhodes, the cellars of which were used as a powder magazine. The explosion destroyed the church and many houses in the neighbourhood. More than 200 corpses were found among the ruins.

Ships are still oftener struck by lightning than buildings, and the danger is increased by the circumstance that but a few planks, which the lightning can easily change into ashes, separate a number of persons from a watery grave. Arago cites forty-two cases of vessels struck by lightning in the Mediterranean and on the coasts of England. In the year 1799 two men were killed and two-and-twenty wounded on board the 'Cambrian' at Plymouth. In 1808 seven men met their death from the same cause in the 'Sultan' at Mahon. The ship 'Golden Fleece' had just left Boston for San Francisco when she was struck by lightning, and took fire. The passengers were obliged to leave her in boats, and the greater part of them perished.

Lightning generally destroys life by an instantaneous extinction of nervous power, by a sudden annihilation of feeling. Hence persons thus killed are frequently found quite unchanged in the situation they were in when struck by the electrical discharge. Cardanus relates that eight reapers taking their meal under an oak were killed by lightning. When the witnesses of the thunderstroke came to see what had happened, the unfortunate victims seemed to be still busy with their frugal repast. One of them held his glass, another was putting some bread into his mouth, a third had his hand in the dish. The angel of death had struck them so violently that the whole surface of their body bore the marks of his black wings. They seemed so many statues sculptured in black marble.

In another case where ten reapers were killed under a hedge, one of them had a dog on his knee at the time when he was struck. The unfortunate man was caressing with one hand his little companion, and with the other giving him a piece of bread. Both master and dog were now merely inert masses of rigid muscle and stiffened sinew, and yet the bread was still held by the lifeless hand. The dog, with his mouth expressively open, seemed still to beg for the proffered morsel.

The rigidity of death produced by lightning is sometimes so complete that the body, petrified, as it were, with the rapidity of thought, remains fixed in a position which the living body would not be able to maintain for more than a few seconds. A peasant woman in the environs of Nancy was gathering flowers, and struck while engaged in this innocent occupation. She was found standing, holding in her hand the daisy she had been plucking.

Mr. Bondin, editor of the 'Annales d'Hygiène,' mentions the case of a priest who was struck dead while on horseback. Strange to say, the animal remained unhurt, and as it knew the road perfectly, and required neither rein nor whip for its guidance, continued to move on with its dead master firmly seated on its back. Thus they arrived at their destination as if nothing had happened.

In consequence of the amazing rapidity of its action which leaves no room for sensation, we have well authenticated cases of people being struck senseless by lightning, who, on recovery, had no memory of pain. The following circumstantial case is described by Hemmer:—On June 30, 1788, a soldier in the neighbourhood of Mannheim, being overtaken by rain, placed himself under a tree, beneath which a woman had previously taken shelter. He looked upwards to see whether the branches were thick enough to afford the required protection, and, in doing so, was struck by lightning and fell senseless to the earth. The woman at his side experienced the shock in her foot, but was not struck down. Some hours afterwards the man revived, but remembered nothing of what had occurred, save the fact of his looking up at the branches. This was his last act of consciousness, and he passed from the conscious to the unconscious condition without pain.

'Under ordinary circumstances,' says Professor Tyndall,[1] 'the discharge from a small Leyden jar is exceedingly unpleasant to myself. Some time ago I happened to stand in the presence of a numerous audience with a battery of fifteen large Leyden jars charged beside me. Through some awkwardness on my part, I touched a wire leading from the battery, and the discharge went through my body. Life was absolutely blotted out for a very sensible interval without a trace of pain. In a second or so consciousness returned. I saw myself in the presence of the audience and apparatus, and by the help of these external appearances, immediately concluded that I had received the battery discharge. The *intellectual* consciousness of my position was restored with singular rapidity, but not so the *optical* consciousness. To prevent the audience from being alarmed I observed that it had often been my desire to receive accidentally such a shock, and that my wish had at length been fulfilled. But while making this remark the appearance which my body presented to myself was that of a number of separate pieces. The arms, for example, were detached from the trunk and seemed suspended in the air. In fact, memory and the power of reasoning appeared to be complete long before the optic nerve was restored to healthy action. But what I wish chiefly to dwell upon here is the absolute painlessness of the shock; and there cannot be a doubt that to a person struck dead by lightning the passage from life to death occurs without consciousness being in the least degree implicated. It is an abrupt stoppage of sensation, unaccompanied by a pang.'

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[1] 'Fragments of Science.' Fourth edition, p. 467.

The visible marks of a lightning stroke are usually insignificant; the hair is sometimes burnt, slight wounds are observed, while in some instances a red streak marks the track of the discharge over the skin. In some cases not even the slightest trace of any material injury can be discovered, while in others the electric stroke entirely destroys the texture of the internal organs of the body, and reduces them into a formless mass. In 1838 some oxen which were struck near Nymwegen, in Holland, had their bones shattered into thousands of fragments as if rent by fulminating powder. In 1718, eight sheep were killed by lightning at Pillniz, in Bohemia. On examining their bodies, it was found that the fragments of their bones were so mingled with the flesh that it could not be used for food.

By an inexplicable caprice the lightning stroke sometimes burns or destroys the clothing of its victims, and leaves their bodies uninjured, while in other cases the contrary takes place. On June 29, 1869, the maire of Pradette (Département de l'Ardèche) unfortunately sheltered himself during a thunderstorm under a high poplar tree. Soon after he was killed by lightning, which stripped him completely, with the exception of a single shoe. On August 11, 1855, a man was struck by lightning on a road near Vallerois (Département Haute Saône) and entirely divested of his raiment, only a few remnants of which could afterwards be found. Ten minutes after the stroke he was restored to consciousness, complained of the cold, and asked how he came to be there without any clothing. No doubt he would have more easily consoled himself for the loss of his apparel had he known of the case reported by Sestier of a man whose whole right side was burnt, as if he had been held for some time over a fire-pan, while his shirt, his drawers, and the rest of his dress, bore no marks whatever of combustion.

Generally the clothes thus rent from the body are consumed or destroyed without being ignited, but sometimes they are set on fire by the lightning. On May 10, 1865, a man named Louis Roussel was struck by lightning on the road from Bapaune to Albert. The body was found completely stripped of its vestments, which were still burning at the time.

In some cases the clothes have been found unstitched, as if the work had been done by hand.

On June 8, 1868, a clerk of the Parisian Gas Company, while passing through the Rue Thouin during a thunderstorm, felt a violent shock, and saw at the same time a vivid flash of lightning. He fell upon his knees, and was seized with a general trembling which lasted some days. On awakening from the stupor into which he had been plunged, he examined his body to see whether he had not been wounded, when, to his great surprise, he found that almost all the nails of his boots had been removed by the lightning.

In a case cited by M. de Quatrefages the stockings were torn into a thousand pieces, and one shoe flung to the other end of the room. Two of its nails were found sticking in the floor, while another following the opposite direction had penetrated to a great depth into the heel of the struck person.

The following effects of lightning are perhaps still more curious. Prof. Perty[1] mentions a thunderstorm which took place on May 24, 1846, near Frutigen, in the Canton of Berne, where the lightning sprang from a pear-tree upon the verandah of a house, where it killed a boy and wounded his mother. The pear-tree and the house were burnt down. On the arm of the wounded woman a remarkably elegant impression of twigs and leaves, like a photographic copy of part of the pear-tree, was found.

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[1] Perty, 'Die Natur im Lichte philosophischer Anschauung.'

In the year 1825, the lightning fell upon the brigantine 'El Buon Servo,' which lay at anchor in the Bay of Armiro, at the mouth of the Adriatic Sea. The superstitious Ionian sailors generally fasten a horseshoe to the foremast of their ships, probably fancying that this simple means affords them protection against the evil intentions of wizards and witches. Of course, the 'Buon Servo' was not without its horseshoe. Antonio Teodoro, of Scarpanto, was sitting near the mast when it was struck by the lightning, and killed at once. No marks of combustion were found on his body, nor were his clothes torn, but on his back was found the distinct impression of a horseshoe of the same size as that which was nailed to the mast.

In the 'Comptes Rendus of the Académie des Sciences' (January 25, 1847), we find that the Signora Morosa, a lady of Lugano, who sat near a window during a thunderstorm, received a shock which did her no further injury, but a flower which stood in the passage of the electric fluid was distinctly pictured upon her thigh. She retained the mark all her life. However strange and incomprehensible these effects of lightning may appear, they are surely not more inexplicable than the wonderful impressions which light makes on a prepared metallic plate, or the transmission of messages through the agency of electric power. All Nature is composed of wonders which it has been given us to admire but not to conceive!

A stroke of lightning not seldom causes a partial paralysis of the arms or legs, or deafness or blindness which sometimes are but of short duration, but often last for days or weeks, or even remain incurable. In some cases persons not mortally struck have been known to lose all their hair and nails. Father Feyjoo, in his 'Cartas Eruditas,' relates that during a heavy thunderstorm at San Jago the lightning struck near to a young man, Juan Menendez Miranda, without wounding him. Nevertheless, his hair soon after fell off, and in a few days he was completely bald.

But as the most virulent poisons change into beneficial medicines in the hands of a skilful or lucky physician, thus also lightning, instead of destroying life, sometimes enables it to cast off disease. The French naturalist De Quatrefages mentions the case of an employé at the telegraph office in Strasburg, who, on June 20, 1831, was struck down senseless by lightning. The paralysis of his limbs lasted till the next day, but afterwards his health was better than it had ever been before. On June 10, 1835, a M. Roalde was paralysed by lightning in the island of Martinique, but three hours after the accident he recovered the use of his limbs. His health, which had hitherto been weak, was considerably strengthened by the concussion.

Cases where rheumatism was cured by a stroke of lightning are mentioned by several authors; and the celestial fire has even been known to make the blind see and the deaf hear, as if to justify the belief of the ancients, that to be struck by lightning is to be a favourite of the gods.

A beneficial influence of lightning upon the growth of plants has often been observed. An avenue of 1,500 poplars leads to the Château of Conacre, near the town of Tours. The lightning struck one of these trees, and left visible marks of its passage on the trunk and the surrounding ground. In consequence of the concussion, the growth of the struck tree acquired a remarkable activity, so that, according to Arago, who verified the fact by ocular inspection, the dimensions of its trunk soon so much surpassed those of all the other trees as to strike even the most superficial observer.

Both Hippocrates and Galenus remark that the water which falls during a thunderstorm is more healthy to drink than that which proceeds from a uniformly clouded sky; and Plutarch mentions that the rain from a thunder-cloud is considered as more favourable to vegetation, and communicates to plants a particular flavour. The production of ozone and nitrate of ammonia by the electrical discharges of a thunderstorm prove the truth of this opinion, and show us that though the ancients knew nothing about the nature of lightning, they were keen and accurate observers of its effects.

With regard to the geographical distribution of destructive lightning-strokes their number is found to vary exceedingly, even over the surface of a country of limited extent. Thus, according to official lists comprising a period of thirty-five years (1835–1869), the several departments into which France is divided are far from being equally exposed to the dangers of lightning. The proportion of victims in the Département de la Lozère, for instance, was thirty times greater than in the Département de la Seine; and while 105 persons were killed in the Département of le Puy de Dôme, only seven were mortally struck in the Département de l'Orne. In general, the greatest number of accidents is found to occur on the central plateau of France and in the more mountainous parts of the country, while the north-western departments adjoining the Channel show a minimum of victims.

In the tropical mountain wildernesses above 13,000 feet high, we find many points of resemblance with the Arctic barren grounds in the same absence of trees, the same naked desolation, the same terrible power of the icy winds. But in the frigid zone, electrical explosions are of very rare occurrence, while in the tropical snow regions they are so frequent that in the highlands of Quito there are scarce sixty days in the year without a thunderstorm. To the naturalist whose researches lead him for some time to the inhospitable Nevadas or snow-fields of the Andes these electrical discharges are a great source of annoyance. In the midst of a dense fog he sees the ground only a few paces before him, and is thus perpetually exposed to the danger of falling into one of the deep crevices which intersect the nevé. Without any protection against the furious gusts of the cold wind, blinded by the lightning, deafened by the incessant roar of thunder, he is moreover pelted with sleet or hail. 'He only,' says Wagner, 'who, cowering on the snow, has for three or four hours been obliged to set a bold front, or rather a patient back, against one of these dreadful storms (the best plan is to wrap oneself up in one's poncho, and, stretched out with one's face to the ground, to wait till the demons of the clouds give up their revelry) can fully estimate the horrors of such a situation. Generally, the traveller, when surprised by the storm, will prefer a hasty retreat to the treeless pasture ground, where he may hope to find shelter in the hut of some Indian shepherd to the alternative of patiently waiting for its termination, stretched out on the cold snow. The descent is indeed very rapid, but full of danger, as, enveloped in a dense mass of vapours, the yawning grave of the ice-crevices can with difficulty be seen. As to ascending still higher during the storm, and facing its fury, even the most hardy mountaineer would never think of such a desperate undertaking.'

Generally, thunderstorms increase in frequency on approaching the equator. In the region of the calms there is one almost every day, and of far greater violence than in our latitudes. But even in the torrid zone there are countries where the lightning is never seen and its attending thunder never heard. On the whole coast of Peru the atmosphere remains in a state of unalterable tranquillity; there no electrical discharges ever terrify the inhabitants; no deluge of rain ever inundates the fields and ruins the hopes of the husbandman. In Egypt, also, thunder and lightning are said to be unknown phenomena. In France, Germany, and England there are seldom more than twenty thunderstorm days in the year, and this number decreases on approaching the pole; so that beyond the 75th degree of latitude no navigator has ever witnessed a thunderstorm. During a sojourn of twenty-eight months in the Arctic seas, comprising three summer periods, Parry observed but one small thunderstorm in Baffin's Bay, about the 70th degree of latitude.

Iceland is also sometimes cited among the countries where it *never* thunders or lightens; but the word *never* is not quite correct, for within a period of about two years (extending from September 21, 1833, to August 30, 1835), during which Dr. Thorstensten made meteorological observations at Reykjavik, the thunder was heard once, on November 30, 1833.

In Western Europe about one-half of the thunderstorms which take place during the year occur in summer, about one-tenth in winter. In Germany and Switzerland the summer storms are still more frequent, while winter storms are very rare, and cease altogether on advancing still farther into the interior of the continent.

At Bergen, on the west coast of Norway, where on an average eight thunderstorms occur during the year, the majority, on the contrary, take place in winter. On the west coast of North America, and on the eastern coasts of the Adriatic, the winter thunderstorms are likewise the most frequent.

It seems that on the high seas thunderstorms are much less frequent than on land. Navigators in the tropical zone have often remarked that they decreased, or even entirely ceased, the farther they sailed from the coasts. From facts stated in several books of travels, Mr. Darwin[1] is inclined to suspect that thunderstorms are very common near the mouths of great rivers, and asks whether it is not possible that the mixture of large bodies of fresh and salt water may disturb the electrical equilibrium of the atmosphere?

[1] 'Journal of Researches.'

CHAPTER XVII.

THE MEANS OF PREVENTING ACCIDENTS BY LIGHTNING.

Illusory Means Used by the Ancients—Places of Refuge—The Emperor Augustus—Bed Mattresses—Seal-skins—Crowns of Laurel—Glass—Best Means to Avoid the Threatened Peril in a House and in the Open Air—The Tolling of Bells Fatal to the Tollers—The Lightning Conductor—Rules for its Proper Construction—Beneficial Effects of Thunderstorms.

THE terrific power of lightning, which menaces both the life and the property of man, has at all times made him anxious to seek protection against its destructive force. Herodotus relates that during a thunderstorm the Thracians shot their arrows towards the sky, as a kind of admonition to the powers above to restore the tranquillity of the disturbed atmosphere; and Moffat informs us that at the present day a similar practice exists among the natives of Namaqua Land, who shoot their poisoned arrows at the lightning in order to arrest the destructive fluid.

The ancients believed that the lightning never penetrates deeper than six feet into the earth. Hence grottoes and caves were, in their opinion, admirable places of refuge. 'At the approach of a storm,' says Suetonius, 'the Emperor Augustus used always to retire into a deep subterranean chamber.' The fulgurites described in the preceding chapter prove how mistaken the Emperor was in his fancied security; and that if Jupiter had been so inclined his thunderbolts might easily have struck the terrestrial god—'divum Augustum'—under the vaults of his palace.

'To increase the protection afforded by thick walls or mounds of earth, the Emperors of Japan,' says Kämpfer, 'have large reservoirs of water placed above the grotto which serves as their refuge during a storm.' But though water is no doubt an excellent conductor, it would be vain to imagine that fishes are completely exempt from the danger of being struck by lightning, for in the year 1670 the thunder fell into the small Lake of Zirknitz, and Valvasor relates that almost immediately after such a number of dead fish came to the surface that the neighbouring peasants filled twenty-eight carts with them. On September 14, 1772, the lightning struck into the river Doubs, near Besançon. Soon after, the surface of the water was covered with stunned fishes, which were swept away by the current.

Among the ancients the belief was universal that a person lying in bed had nothing to fear from lightning, and this opinion has still some adherents at the present day. The case of Mr. Hearthley, who was struck dead by lightning in his bed on September 29, 1772, at Harrowgate, and that of a servant girl who perished in a similar manner at Confolens, in the Department of La Charente, need hardly be cited to prove how little this preservative is to be trusted.

Many people believe that a bed mattress affords ample protection against lightning. Their mistake is proved by the thunderstorm which, on September 5, 1838, completely perforated the mattresses of two beds in a caserne at Lille.

Among the Romans seal-skins were considered as an infallible preservative against lightning. Timorous persons anxiously crept into a tent covered with seal-skins when a storm was impending; and the Emperor Augustus, who seems to have been particularly afraid of thunder, had always a seal-skin near at hand. Arago relates that in the Cevenne Mountains, where Roman colonies were founded, the peasants carefully collect the skins of serpents, which they wear round their hats, and, armed with this talisman, fearlessly brave the storm. Probably, these serpent-skins replaced among the people the more rare and costly seal-skins, which could only be purchased by the rich.

At the approach of a storm the Emperor Tiberius always wore a crown of laurels, for the lightning was supposed never to strike the plant which was consecrated to Apollo.

At the present day the Chinese put the same trust in the mulberry and peach trees; but experience has proved that every plant supposed to enjoy an immunity from lightning has been as frequently struck as any other.

Glass has also been supposed to remain untouched by lightning, and in this belief large glass cages have been made for the use of persons afraid of being struck. Arago, however, has very great doubts of their efficacy, as lightning sometimes strikes circular holes into glass panes.

Numerous instances prove that lightning never strikes a person without chiefly attacking the metallic parts of his dress. Ladies robed in silk, which is a bad conductor, may thus be supposed to run less danger than those who wear a superfluity of golden trinkets.

In a house the best means to avoid the threatened peril is to place oneself at a distance from all good conductors, such as chimneys, gilt mirrors or picture frames, lustres, or burning candles. It is therefore proper to withdraw into the middle of a room, provided no metallic body be suspended from the ceiling; and here, according to Dr. Franklin, almost all possible danger may be avoided by bringing a bed or mattress and placing on it the chair in which we sit.

As the human body is a good electrical conductor, some physicists are of opinion that the risk of being struck while at church increases with the number of the congregation. The vapours arising from a large assemblage of animals are likewise able to attract lightning. For this reason it frequently falls upon flocks of sheep, killing a great number of these animals with a single stroke.

If we are in the open air and overtaken by a thunderstorm, it is proper to avoid all high and pointed objects, except trees, perhaps; but we must not come very near these, keeping only at such a distance as may prevent our being injured by the splinters of wood if the tree should be stricken. It is particularly necessary to avoid rivers and brooks, as these are excellent conductors.

As high trees are often struck by lightning, and a thunderstorm is always very much weakened on passing over a forest, trees planted at a certain distance from a building may be supposed to afford it some protection against lightning. Columella relates that Tarchon, an ancient Etruscan augur, supposed to have been born with white hair, as a sign of precocious wisdom, recommended the planting of white vines round a house as a sure preservative against lightning; but the experience of centuries has by no means verified the truth of Tarchon's assertion.

The kindling of a strong fire has been considered as a good means for dissipating a thunder-cloud, but according to the facts stated in the chapter on rain it would seem to have the contrary effect. The agricultural counties of England are said to be more frequently visited by thunderstorms than the manufacturing districts, where numerous blast furnaces pour out their flames against the sky, but possibly this may be occasioned by the different nature of the soil.

Seamen are in general convinced that the firing of guns dissipates thunder-clouds, but they give us but few proofs of the justness of their belief. In several countries the agriculturists are likewise of this opinion, and discharge cannons at the approach of a thunderstorm. Perhaps they would save themselves this trouble if they knew that during the bombardment of Rio Janeiro by the French Admiral Duguay Trouin, on September 20, 1711, a terrific storm joined its thunders with those of the French artillery; and that the 'Duke,' an English ship of the line, was struck by lightning in 1793, while it was exchanging shot with a battery on the island of Martinique.

According to an ancient superstition the tolling of church bells is supposed in many countries to have the power of averting lightning; but this practice, which most certainly has no influence whatever on the electric fluid, has beyond all doubt cost the life of many an unfortunate toller, as steeples, from their height, are very liable to be struck, and the generally damp bell-ropes act as excellent conductors. Reimarus collected instances of the lightning having struck 386 steeples within the space of 33 years, and killed 121 persons while engaged in tolling the bells. Probably these humble officials of the church would have lived many a year longer if they had not been sacrificed to an absurd custom.

While all the above-cited preservatives against lightning are thus either completely illusory, or furnish at best but an imperfect security, Dr. Franklin's grand discovery of the real nature of lightning has provided us with the means for effectually preserving our churches and palaces, our museums and our dwelling-houses, from the formerly inevitable devastation of the electric fluid. Here, too, the genius of Franklin led the way; and as he certainly deserves the greatest share of the merit due to the discovery of the identity of lightning and electricity, we are also chiefly indebted to him for the means of rendering this knowledge beneficial to mankind. He was the first to recommend the use of pointed metallic conductors attached to the building as a security against the effects of lightning, and this proposal, like most of his ingenious contrivances in electricity, was the result at once of acute reasoning and accurate observation.

Dr. Franklin considered the earth as performing the office of a conductor in restoring to the atmosphere the electrical equilibrium that had been disturbed by the causes which tend to produce atmospherical electricity.

In its course he observes that the lightning will commonly strike the best conductors; and, accordingly, as a metallic rod is a much more perfect conductor than the materials of which buildings are chiefly composed, the lightning will strike the rod in preference to the materials of the building. He therefore advised that a metallic rod should be affixed to some part of the building, penetrating for some distance into the moist earth; and, as lightning does not in every case strike the highest parts of a building, that the rod should extend for some feet above these, in order, as it were, to solicit the lightning.

Experience has fully proved the efficacy of the protective instrument thus invented by Franklin in 1755, but it has at the same time shown that it must be constructed with great care, as otherwise it is likely to attract or increase the danger which it is meant to remove.

There are two principal parts in a lightning conductor—the rod and the conductor. The rod is a pointed bar of iron, the top of which is either gilt or terminated with a needle of platina soldered to it with silver. Its basal section must be about two or three inches in diameter, as lightning has been found to destroy bars of inferior strength, and it should rise at least ten feet above the highest parts of the building.

The conductor is a bar of iron which descends from the bottom of the rod to the ground, which it penetrates to some distance. As in consequence of their rigidity iron bars cannot always be well adapted to the exterior of buildings, lightning conductors are best formed of wire cords, such as are used for rigging and for suspension bridges.

It is essential that the conductor be perfectly uninterrupted, or, if formed of several pieces, that their junctions be as nearly in contact as possible. Abundant observation has proved the danger of having discontinuous conductors either attached to a building or forming part of the materials. About the middle of last century the steeple of St. Bride's Church in London was struck by lightning and greatly injured. In the construction of this steeple a great deal of ironwork had been employed, the stones having been fastened together in many places by iron cramps, the ends of which were covered with small stones. The lightning seems first to have struck the vane of the spire, from which it was safely conducted down the shaft by which the vane was supported; from the extremity of this shaft it leaped to two cross iron bars which were at the base of the obelisk, shattering it in its way. Hence it passed to one of the above-mentioned cramps, and thus from cramp to cramp, throwing out or demolishing the stones as it passed along.

The conductor is usually led into a well, and, to connect it better with the soil, it ends in two or three branches. If there is not a well in the neighbourhood, a hole is dug in the soil to a depth of six or seven yards, and the foot of the conductor having been introduced, the hole is filled with wood-ashes or powdered coke, which conduct very well, and yet preserve the metal from oxidation.

Experience has shown that approximately a lightning conductor protects a circular space around it, the radius of which is double its height. Thus a building sixty-four yards in length would be protected by two rods eight yards in height, at a distance of thirty-two yards.

The action of a lightning conductor depending on induction and the power of points, Franklin, as soon as he had established the identity of lightning and electricity, assumed that lightning conductors withdrew electricity from the clouds; but the converse is the case. When a storm-cloud, positively electrified, for instance, rises in the atmosphere, it acts inductively on the earth, repels the positive and attracts the negative fluid, which accumulates in bodies placed on the surface of the soil, the more abundantly as these bodies are at a greater height. The tension is then greatest on the highest bodies, which are therefore most exposed to the electric discharge; but if these bodies are provided with metallic points, like the rods of conductors, the negative fluid withdrawn from the soil by the influence of the cloud flows into the atmosphere, and neutralises the positive fluid of the cloud. Hence, not only does a lightning conductor tend to prevent the accumulation of electricity on the surface of the earth, but it also tends to restore the clouds to their natural state, both which concur in preventing lightning discharges. The disengagement of electricity is, however, sometimes so abundant that the lightning conductor is inadequate to discharge into the ground, and the lightning strikes; but the conductor receives the discharge in consequence of its greater conductivity, and the building is preserved.

The damage caused by thunderstorms, the tribute they levy on the life and property of man, should not make us forget their far greater services. Lightning strikes comparatively but seldom with destructive effect; but every thunderstorm purifies the air and imparts new energies to vegetable and animal life. All Nature seems renovated; the fields and woods smile with a fresher green, and exhale perfumes which are never more delightful than after a thunderstorm. Its salutary influence on the health of man, though apparent in every clime, is nowhere more striking than during the rainy season in the tropical zone. Here, everybody feels a remarkable nervous depression and lassitude before the thunderstorm; and as these sensations are not experienced during the warmer part of the day in the dry season, they cannot be the result of heat alone. Incapable of exertion, and plunged alike in torpid indolence, the negro, the Indian, and the European, long for the electrical discharges which relieve both body and mind from this peculiar oppression. After the thunderstorm, the backwoodsman again seizes his axe, the coloured porter willingly resumes his heavy load, and the white merchant is again busy at his desk, reckoning his profits or counting his dollars, while previously to the storm he had lost all inclination even for these favourite pursuits.

CHAPTER XVIII.

THE CYCLONE.

Vast Destructive Power of the Cyclone—The Cyclone of Barbadoes, 1831—The great West Indian Cyclone of 1780—Dimensions of Cyclones—Calm in the Centre of a Cyclone—Sudden Squalls Particularly Dangerous to Vessels—Storm Scuds—Dampier's Description of a Chinese Teifun—Signs of an Approaching Cyclone—Rapidity of its Movements.

ALL the most appalling features of an ordinary thunderstorm attain colossal dimensions in the tropical cyclone. Like fire driven by the wind over a parched prairie, its irresistible fury consumes everything in its track; like the earthquake, it strews whole provinces with ruins. It is generally preceded by a dreadful stillness of the elements and a misty haze in the atmosphere, which gives the sun a lurid tinge, and makes the stars appear larger. But a dreadful commotion follows upon this treacherous calm. The sky is suddenly overcast and wild; the sea rises at once from a profound repose into mountain billows; the wind rages and roars like the noise of cannon; the rain descends in deluges. A dismal obscurity envelopes the earth with darkness; the upper regions of the air appear rent with thunder and lightning; the earth seems to tremble; terror and consternation distract the whole face of Nature. Birds are swept away from the woods into the ocean, and those whose element is the sea seek for refuge on land. The frightened animals in the fields flock together, and are nearly suffocated by the impetuosity of the wind in seeking for shelter, which, when found, serves them only for destruction. The roofs of houses are carried to vast distances from their walls, which are bent to the ground, burying their inhabitants under their ruins. Large trees are torn up by the roots, and huge branches shivered off and driven through the air in every direction with immense velocity. Every tree and shrub that withstands the shock is stripped of its boughs and foliage, and luxuriant spring is changed in a moment to dreary winter. This direful tragedy ended, when it happens in a town, the devastation is surveyed with accumulated horror; the harbour is covered with wrecks of boats and vessels, and the shore has not a vestige of its former state remaining. Mounds of rubbish and destroyed buildings in one place, heaps of earth and trunks of trees in another, deep gullies from torrents of water, and the dead and dying bodies of men, women, and children, half buried and scattered about where crowded streets but a few hours before afforded the pleasing spectacle of busy life, all combine to form a picture of utter desolation with famine and disease louring in the background of the dreary scene.

The fury of the cyclone will appear still more forcibly when pictured in individual instances, and show that the terrestrial convulsions of the earthquake can hardly surpass the convulsions of the atmosphere in destructive rage. An eye-witness thus describes the cyclone of August 10–11, 1831, in Barbadoes:—

'After midnight, the uninterrupted flashing of the lightnings became terrible and grand, and the storm raged fearfully. At one o'clock on the 11th, the wind increased in violence, and suddenly veered from the NE. to the NW. The upper regions of the atmosphere were meanwhile furrowed with incessant lightnings; but these vivid flashes were surpassed in brilliancy by the streams of electric fire which exploded in every direction. A little after two o'clock the howling of the storm was such that no language is able to describe it. Lieut.-Col. Nickle, commander of the 36th Regiment, had sought refuge under an arcade of a lower storey of his house, and was prevented by the dreadful noise of the storm from hearing the falling in of the roof and upper storey. At three o'clock the wind diminished, but furious gusts came alternately from the SW., W., and WNW.

'A few minutes later the lightning also ceased, and the tenfold darkness which now enveloped the town was indescribably dreadful. Fiery meteors now fell from the sky; one particularly, of a globular form, and blood-red colour, dropped down perpendicularly from a considerable height. This meteor fell decidedly by its own weight, not driven by an external force. As it approached the earth with increasing rapidity, it became dazzlingly white and of an elongated form. On touching the ground in Beckwith Square it burst into a shower of sparks like a ball of fused metal, and was instantly extinguished. A few minutes after this phenomenon the howling of the wind abated to a majestic murmur, and the lightnings which since midnight had flashed in zigzags now appeared for half an hour with new and surprising vivacity between the clouds and the earth. The great mass of vapours appeared to touch the houses, and sent flames downwards which rapidly again sprung upwards from the earth.

'Immediately afterwards, the storm again broke in from the west with indescribable fury, driving thousands of ruins before it like missiles. The strongest buildings shook to their foundation; nay, even the earth trembled as the destroyer passed over it. No thunder was to be heard for the dreadful howling of the wind; the roar of the ocean whose mighty waves threatened to destroy all that the other elements might spare, the rattling of the tiles, the falling in of roofs and walls, formed altogether a terrific chaos of sounds. After five, the storm abated; and now the falling of the tiles and bricks was distinctly heard, which the last gusts had probably swept high up into the air. At six o'clock the wind was south, and at nine the weather was fine.

'As soon as the twilight rendered objects visible, the writer went upon the quay. The rain fell with such violence that it hurt the skin, and so thick that one could not see farther than the end of the mole. The aspect was beyond all description sublime. The waves rolled gigantically towards the shore as if nothing could withstand their violence; but as soon as they broke upon the quay they lost themselves under rubbish of every description. Beams, cordage, casks and goods, formed a continuous undulating mass. Only two vessels remained upright; many were overturned, or lay on the lee side in shallow water. From the tower of the cathedral a scene of universal destruction presented itself. The aspect of the country was like that of a desert; it seemed as if fire had gone over the land, devouring and burning everything before it. Some few trees stripped of their leaves and branches presented a cold and wintry aspect, and the numerous country houses about Bridgetown, formerly shaded with dense bushes, now lay bare and in ruins.'

Professor Dove adds to this description that when the storm was at its highest, electrical sparks sprang from a negro in the garden of Codrington College, so great was the electrical tension of the atmosphere. Reid consequently assumes that the reason why a great number of forest trees died at St. Vincent without having been blown down may possibly have been this excess of free electricity. This storm, like several others, was also remarkable for a salt-water rain. At the north end of Barbados the waves constantly broke over a cliff more than seventy feet high. Their spray was carried many miles inland, so that in the ponds of Major Leacock all the sweet-water fish died.

In the Great West Indian cyclone of October 10, 1780, which from its destruction of Sir George Rodney's fleet has also an historical interest, we find combined on the grandest scale all the terrors of these dreadful atmospherical convulsions. Its original breadth was so immense that it embraced at the onset the extreme limits of the Lesser Antilles—Trinidad and Antigua—while its centre passed on October 10 from Barbados to Santa Lucia, where Admiral Hotham was stationed with the 'Vengeance,' 'Montagne,' 'Egmont,' 'Ajax,' 'Alkmene,' and 'Amazon.' It then assailed on the south coast of Martinique the French convoy, which under the frigates 'Ceres' and 'La Constante' consisted of fifty merchant vessels and transports, with 5,000 men on board. Only six or seven ships escaped its fury. 'The vessels of the convoy disappeared,' is the laconical expression of the Intendant of Martinique in his report to Government.

The centre of the cyclone then passed over Porto Rico, where the 'Deal Castle' foundered, to the Island of Mona, where, on the morning of the 15th, it met and roughly handled the English convoy under the 'Ulysses' and the 'Pomona.' Hereupon it proceeded to the Silver Keys, where it sank the 'Stirling Castle.' The spot where the 'Thunderer,' sailing at the time from Santa Lucia to Jamaica, was lost, has never been ascertained. Under 26° N. lat. the cyclone now swept round to the north-east, where it met with the shattered squadron under Admiral Rowley, consisting of the 'Trident,' 'Ruby,' 'Bristol,' 'Hector,' and 'Grafton,' which had but seven days before escaped a hurricane at Savanna la Mar, on the west coast of Jamaica. In this hurricane the 'Scarborough,' 'Barbados,' 'Victor,' and 'Phœnix,' had gone down, and the 'Princess Royal,' the 'Henry,' and the 'Austin Hall,' been torn from their anchors and thrown so high on shore that they afterwards served as dwellings to the surviving inhabitants.

Advancing towards the Bermudas, the cyclone overtook the 'Berwick,' which, disabled by the previous storm at Savanna, was on its return to England; and on October 18, it cast 50 ships ashore.

On the islands themselves it had raged with fearful violence. Nine thousand persons lost their lives at Martinique; 1,000 alone, in the small town of St. Pierre, where the sea rose 25 feet high, and left not a single house standing. At Fort Royal the cathedral, 7 churches, and 1,400 houses were thrown down, and 1,600 patients buried under the ruins of the hospital. In Dominica almost all the houses built along the shore were destroyed; and at St. Eustace only 1 of the 19 vessels that were torn from their anchors returned to port. In St. Lucia, where 6,000 persons were killed, the strongest buildings were demolished. Of the 600 houses of Kingston, in St. Vincent, only 4 remained standing; the others were razed to the ground.

'It is impossible,' says Sir George Rodney in his official report, 'to describe the dreadful spectacle which Barbados exhibits. I am perfectly convinced that the violence of the storm has prevented the inhabitants from feeling the earthquake, which, beyond a doubt, accompanied it; for only an earthquake is able to destroy the most massive buildings down to their foundations. The devastation is so complete that no church, no house, has escaped it.'

In Barbados, the evening which preceded the storm had been remarkably quiet, but the sky uncommonly red and fiery. Rain fell during the night, and on the morning of the 10th much rain with wind from the north-west. At ten o'clock the wind increased, and at one o'clock the ships in the harbour began to drive on their anchors. At four o'clock all the ships went out to sea; at six o'clock the wind had already blown down many trees. In the Government House care had been taken to barricade the doors and windows, but without much effect; for at ten the wind broke into the building from NNW. The family sought refuge in a central room, the walls of which were three feet thick; but at half-past eleven, the storm which had carried away the roof drove them into the cellar. There also there was no abiding, as the water rose in it four feet high. The family now fled under the cannons—a dreadful situation, as many cannons were moving, and they had to fear that the one which sheltered them might be lifted out of its carriage and crush them in its fall, or that the fragments which were flying about in all directions might put an end to their lives. At break of day not a building in the town was standing; the trees, if not torn up or broken, were stripped of their branches and leaves, and delicious spring changed in this one night into naked winter.

The number of the killed in Barbados was estimated at several thousands. Here, also, the fortifications suffered considerably, for the storm was so violent that a 12-pounder was driven on its wheels to a distance of 420 feet from the south to the north battery.

The enmity of man is silenced by an elementary war like this. When the 'Laurel' and 'Andromeda' stranded at Martinique, the Marquis de Bouillé sent the twenty-five seamen who had been saved from death to the English governor of Santa Lucia, with the generous remark that he could not retain these victims of a general catastrophe as prisoners.

According to the researches and observations of Redfield, Reid, Piddington, &c., the cyclones are great rotatory winds describing a vast curve as they proceed. Piddington first distinguished them by their now universally adopted name, from the storms which move along in a stream-like direction, and whose different degrees of strength he designated by the old denominations of 'breeze,' 'gale,' 'storm,' and 'hurricane.' In the Polar regions and on the coasts of England and North

Germany, the stream-like storms seem to be the most common and dangerous. They set in with a SSW. and SW. wind, and generally end through a change in their direction with WNW. and NW. The cyclones begin to be more common in the Irish coasts; and in the Atlantic Ocean, and particularly in the North American and West Indian waters, they are much more frequent and terrible than the stream-like storms.

The velocity and violence of the wind within a cyclone increases from its borders to the centre. Thus in the Cuba cyclone of October 4–7, 1844, Redfield estimates the entire breadth of the sea on which the wind was perceptibly strong, or where the weather had a stormy appearance, at more than 900 miles, the diameter of the part where it blew a gale at 800 miles, and that of the central part, where the wind had a hurricane velocity, at more than 500 miles.

Redfield ascribes to the West Atlantic cyclones a diameter of from 50 to 300 miles; but sometimes, as in the above-mentioned instance, their lateral extent increases to 1,000 or even 1,500 miles, particularly on their advancing into higher latitudes.

In all the more accurately observed cyclones gradual expansions and contractions have moreover been ascertained. The smaller cyclones seem to be the most violent, such as the Teifuns, the dreadful cyclones of the Chinese Sea, to which Piddington ascribes a diameter of from 60 to 240 sea miles, or the smaller cyclones of the Bay of Bengal, which, like the land tornados, literally destroy everything on their passage, although they are only 300–1,000 yards broad. The Atlantic cyclones are also much more violent in those parts where they are narrowest.

In the centre of a cyclone the winds are weak and variable, or there is a complete calm. This dreadful silence in the midst of the most appalling elementary war has been ascertained in numerous cases. A letter from Nassau (Bahama Islands), August 1, 1813, cited by Professor Dove, mentions that about two o'clock in the afternoon the storm attained its greatest height, and its rage lasted till five o'clock, when it suddenly ceased. For the next half-hour it was followed by so complete a calm that the awful stillness could only be compared with death after the most dreadful convulsions. The colonists, acquainted with the nature of the cyclone, made use of this interval to take every precaution against its recurrence, which they expected from the southwest. It made its appearance with the greatest rage at about six. 'In Antigua,' as Fitzroy[1] relates, 'the hurricane of August 12, 1835, also blew during its first period from the north, and then after a calm of twenty minutes from the south.' The diameter of the calm belt has been calculated by Thom at twenty-one sea miles for the Mauritius cyclone of April 1840, and by Piddington for the Calcutta cyclone of 1842 at eleven miles. The central calm belt of an East Indian cyclone, which occurred in November 1845, was ascertained to have been thirty sea miles broad, while the storm on each side had a width of no more than thirty-five miles. A complete calm in the centre of a cyclone takes place, however, only within the tropics. Beyond the torrid zone there is only a lull, which, however, generally expands as the cyclone progresses towards higher latitudes.

In very wide-spread cyclones[2] the region of weaker and irregular winds on both sides of which the storm rages, sometimes attains a diameter of several hundred miles. And in those cases also where a total calm reigns in the centre there is generally a transition to the hurricane through a lull or heavy gusts of wind.

In general the cyclone does not blow with uniform strength, but in violent gusts or squalls. These sudden shocks, which are sometimes preceded by short calms, render the cyclone so extremely dangerous to ships, the more so as their direction is almost constantly changing. Not unfrequently, particularly in winter and land storms, the winds on different sides of the cyclone axis are very unequal in violence and extent. Sometimes also two or more cyclones blow at the same time, and partially overstep each other's bounds.

Thick clouds and heavy falls of rain are the constant companions of cyclones, generally also thunder and lightning. Mr. Thom[1] declares that no phenomenon so regularly accompanies the Indian cyclones, or is so astonishing, as the enormous quantity of water which falls from the agitated atmosphere. For hundreds of miles on all sides of the whirl a thick layer of clouds is perpetually pouring down torrents of rain. The approach of such a storm can almost be predicted from the uninterrupted cloud stratum which slowly overcasts the sky, at first at a great height, but gradually descending, and accompanied by increasing darkness until it finally rests upon the earth and begins to pour forth a deluge. These signs are observed at a distance of 200 or 300 miles from the whirlwind, and might warrant the conclusion that the commotion of the air in the upper regions is far greater than at a lower level.

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[1] 'The Weather Book: a Manual of Practical Meteorology.' Sixth edition, 1863.

[2] Redfield, 'Silliman's Journal,' January, 1842.

The condensation of the aqueous vapours extends, as Thom elsewhere remarks, much farther along the front than at the back of the cyclones.

Between the great stratus-cloud above and the surface of the earth the characteristic storm-scuds sweep along at a comparatively small height, which Redfield estimates at from 500 to 2,500 feet. The numerous observations he made from 1832 to 1842 showed him that without a single exception their movement is not like that of the winds which blow towards the centre of the cyclone, but that they are swept away in the opposite direction. The height to which they are driven by this centrifugal movement accounts for the prognostics of the storm being often observable in the region of the clouds for many hours before a change in the movements of the air takes place below.

Dampier gives a short but graphic account of these premonitory signs in his description of the Chinese Teifuns on the coast of Tonquin. 'Before these whirlwinds approach, a heavy cloud appears in the north-east, very black below near the horizon, of a deep red colour farther up, and finally quite above fallow and of a whitish colour which blinds the eye. This dreadful cloud is often seen twelve hours before the arrival of the whirlwind. When it begins to move rapidly, one may rest sure that the storm is at hand. The wind comes with great violence, and blows during twelve hours more or less from the north-east, accompanied by horrible thunderclaps, rapid and frequent lightnings, and very heavy rain. When the wind begins to abate, the rain suddenly ceases, and a calm ensues. This lasts about an hour, and then the wind blows from the south-west as long and as violently as it did before from the north-east.'

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[1] 'An Inquiry into the Nature and Course of Storms in the Indian Ocean South of the Equator.' London.

The centrifugal movement of the storm in the upper regions is also announced by a fall of the barometer, which is generally the first sign of an approaching cyclone.

The fall of the barometer, which by giving timely notice has saved many a vessel from destruction, invariably increases towards the centre of the cyclone. The barometrical observations made during the Cuban hurricane of October 4–7, 1844, may serve as an example:

Barometer .	29″76	29″50	28″84	28″13	28″45	29″45	29″86
At a distance of	349	260	126	0	98	230	375
English miles to the		left		and to the		right	

from the centre of the cyclone.

In general the fall of the barometer appears to be much more rapid within the tropics than in the temperate zones, but as the width of the cyclones increases as they advance into higher latitudes, the fall of the mercury takes place at greater distances from the centre. Consequently, the total diminution of the atmospherical pressure is much more considerable in the temperate zones than in the tropical regions; in the former it may be compared to a wide valley with gradually sloping sides, in the latter to a deep gulf with precipitous walls.

The cyclones generally begin in the torrid zone, and then in most cases advance in parabolic curves into the temperate, and sometimes even as far as the frigid, zones. Many cyclones, however, originate in the temperate regions, and these, as far as we know, always move towards the east. Maury draws attention to the fact that the West Indian cyclones, after having reached the Gulf Stream, follow its course.

It would be erroneous to suppose that the cyclones begin at the point where they were first noticed. Many of the

Atlantic hurricanes have evidently an African origin; as, for instance, the cyclone of August and September 1853, which, after crossing the ocean from Cape Verde to America, turned on the coasts of the United States, then grazed on one side Newfoundland and on the other the west coast of Great Britain, and finally, after a disastrous course of thirteen days, lost itself in the Polar Sea.

The rapidity with which the centre of the cyclone advances in its curvilinear movement is far inferior to that of the wind within its vortex. The latter amounts to one hundred and more sea miles in an hour; the former in general only to from fourteen to twenty sea miles in the West Indian cyclones. Redfield, however, has shown that in the higher latitudes the Atlantic cyclones often proceed with a rapidity of fifty English miles in an hour; and, according to Mohn's investigations, the European cyclones regularly advance at the rate of from twenty-four to thirty sea miles per hour.

The progressive movement of cyclones is not so great in other seas. In the Indian Ocean it only amounts to from three to ten sea miles; in the Bay of Bengal, according to Piddington, to from three to fifteen; and in the Chinese seas to from seven to twenty-four sea miles per hour. In the Indian Ocean even stationary cyclones have been observed. That of May 12–19, 1863, for instance, advanced on the second day only one foot in a second.

The progressive movement of the centre not only differs considerably in various cyclones, but is also very unequal in one and the same storm.

The above-mentioned Cape Verde cyclone, for instance, described in 284 hours a course of 7,272 miles, or advanced on an average twenty-six miles in an hour; its rapidity, which in the torrid zone was no more than twenty-two miles, diminished at the turning-point to thirteen miles, and increased in the higher latitudes to fifty miles.

As a revolving carriage-wheel advances at the same time with its axle, thus also the air in the cyclone, while whirling round the centre, participates in its progressive movement. In the northern hemisphere the rotatory movement follows a direction contrary to that of the hands of a clock, while the opposite takes place in the southern hemisphere.

The knowledge of the laws which regulate the movements of cyclones is of great practical importance to the mariner, since it points out to him the direction in which he has to steer in order to remove as soon as possible beyond the reach of danger, and thus the men whose patient investigations have traced the march of these tremendous storms, and pointed out the track they are forced to pursue, have not only rendered service to science, but rank highly among the benefactors of mankind.

The origin of cyclones is in all probability due to the encounter of two currents of air moving in opposite directions. Thus the West Indian cyclones are most frequent between the months of August and October, when the heated shores of South America are beginning to attract towards them the colder air of North America. In the Indian and Chinese seas they generally take place at the change of the monsoons, when the conflicting masses of air loaded with electricity enter into a struggle for the mastery, and produce a rotatory movement round a neutral point as they come into collision, even as the Maelstrom is produced by the meeting of conflicting currents.

CHAPTER XIX.

THE SAINT ELMO'S FIRE.

Superstitious Notions of the Ancients—Castor and Pollux—Helena—The Phenomenon frequently mentioned by Ancient Historians—Columbus and Magellan—Admiral Forbin—Electrical Emission of Light on Branches—On the Summits of Mountains—Adventure of Professor Siemens on the Pyramid of Cheops—Electrical Aureolas—Luminous Rain—Luminous Dust—Causes of the St. Elmo's Fire and of the Analogous Phenomena.

BESIDES the discharges of atmospherical electricity which take place with terrible explosions, and not seldom with destructive violence, there are others of a more harmless nature, unaccompanied by the rolling of thunder or the flashing of incendiary lightning. Of this kind is the appearance of small flames or jets of fire, which are sometimes seen to issue in stormy weather from prominent objects, such as the masts of ships or the points of lances.

A phenomenon so striking could not fail to attract attention since the remotest times, and we consequently find it playing a part in the mythology of the ancients, and repeatedly mentioned in their historical annals.

Diodorus Siculus relates that the ship 'Argo,' having been assailed by a tempest during the expedition of Jason to Colchis, Orpheus implored the gods of Samothrace, when two stars placed themselves upon the heads of Castor and Pollux, who took part in the Argonautic voyage, and the danger immediately ceased. Ever since, adds the historian, the sailors, when threatened by a storm, invoke the gods of Samothrace, and when the two stars appear they are attributed to the tutelary presence of Castor and Pollux, the sons of Jupiter and Leda, and hailed as the certain signs of a prosperous voyage. The appearance of a single flame or star, on the contrary, was supposed to forebode disaster and shipwreck, and attributed to the presence of mischief-making Helena, the ill-famed sister of the Dioscuri. Such was the strange fabric of superstition built upon a simple physical phenomenon!

While the fleet of Lysander was on the point of sailing from the port of Lampsacus to attack the fleet of the Athenians, Plutarch tells us that the stars Castor and Pollux appeared one on each side of the ship of the Lacedemonian admiral, who soon after, by surprising and capturing the Athenian fleet at Aigos Potamoi, destroyed the supremacy of Athens, and made Sparta for a time the leading state of Greece.

'ST. ELMO'S FIRE' ON MASTS OF SHIP AT SEA.

The appearance of jets or brushes of flame on the points of lances and javelins was always considered by the ancients as a lucky omen. Thus when Gylippus on his march to Syracuse saw a star resting upon his lance, he was highly rejoiced at this sign of divine favour. According to Dionysius of Halicarnassus,[1] the Romans in the year 251 of Rome, when about to fight against the Sabines with inferior numbers, were greatly encouraged by the flames which appeared on the long iron points of the lances they had stuck into the ground.

Hirtius Pansa, in his 'Commentaries on Cæsar's African War,'[2] relates that in a stormy night, during which a great fall of hail took place, the points of the standards of the fifth legion were seen to emit flames, a circumstance which inspired the army with the confidence of victory; and, according to Procopius, a similar phenomenon appeared on the lances of the soldiers of Belisarius, during the war against the Vandals.

We have also read in Valerius Maximus,[3] that while the centurion L. Marcius was haranguing the Roman troops, who were greatly dispirited by the death of P. and Cn. Scipio in Spain, a flame was seen on his helmet. This *prodigy* had a wonderful effect in raising the courage of the soldiers, who soon after gained a great victory over the Carthaginians.

Though in our days Castor and Pollux are no longer invoked by seamen, yet St. Elmo's fire, as the phenomenon is now called, still maintains its ancient ominous significance among the mariners of the Mediterranean; for though religions and customs change, superstitious ideas are transmitted from century to century.

'On Saturday night' (October 1493), writes Don Diego Columbus in his history of his father's voyage, 'it thundered and rained very much. St. Elmo then showed himself in the foremast with seven lighted tapers—that is, the fires were seen which the sailors suppose to be the body of the saint. Immediately many litanies and prayers were sung on board, for seafarers are persuaded that all danger is past as soon as San Elmo shows himself.'

Herrera informs us that the companions of Magellan shared the same superstition. 'During a great storm,' says the historian, 'St. Elmo showed himself upon the masts, sometimes with one light, at others with two. These phenomena were welcomed with exclamations and tears of joy.'

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[1] 'Antiquit. Roman.' v. 46.

[2] Bell. Afric. cap. 41.

[3] Dictorum Factorumque memorabilium Libri—De Prodigiis.

The French admiral Forbin relates in his 'Memoirs' another remarkable instance of St. Elmo's fire, which came under his observation in 1696 near the Balearic Islands. 'The night suddenly became profoundly dark, with terrible thunder and lightning. Fearing a heavy gale, I ordered the sails to be reefed. We saw upon the ship more than thirty of St. Elmo's fires. One among others at the top of the vane of the mainmast was above a foot and a half high. I sent up a sailor to bring it down. When he was at the top of the mast he called out that the fire made a noise like that caused by the burning of wet powder. I ordered him to take off the vane and to come down, but scarce had he detached it when the fire left the vane and settled on the top of the mast, so that it was impossible to remove it. It remained there some time, and then gradually disappeared.'

The near relationship of the St. Elmo fire and the thunderstorm is plainly revealed in the following instance:—In March 1866, one of these mysterious flames appeared in stormy weather on the top of the mainmast of an iron steamer navigating in the Channel. The captain had the curiosity to examine it close by, and found to his surprise that it emitted no appreciable heat. His own body now served as a conductor to the electrical disengagement, and jets of fire were projected from his fingers' ends without causing any shock or commotion. The phenomenon followed all the fluctuations of the storm. Whenever the wind blew more violently, and the rain fell more heavily, the harmless light increased in splendour.

Similar observations were made in the Atlantic on board the packet-boat 'Imperatrice Eugenie' on the night of December 23, 1869. The weather was squally, accompanied with showers of hail, and luminous brushes of a bluish colour a foot and a half high appeared at the points of the conductors on every mast, while the rigging shone with a phosphoric gleam. These lights made their appearance as soon as the squall reached the ship. Extremely brilliant whenever the wind blew with all its violence, they diminished in splendour whenever it abated, and entirely disappeared with its cessation. Only those parts of the rigging which faced the wind were illuminated; the others were all plunged in darkness, and the phosphoric gleam did not descend lower than about ninety feet from the level of the sea. The phenomenon showed itself several times in the night, but only during the intervals of gusty weather accompanied with hail.

Electrical emissions of light, similar to the St. Elmo fire, have not seldom been observed on the points of branches. In November 1856, Herr Kleefeld was travelling through a hilly and wooded district in the neighbourhood of the town of Dantzig. On his way he was overtaken by one of those drizzling fogs which are common on the coasts of the Baltic, and about half-past six in the afternoon a terrible thunderstorm completely darkened the air. Soon after he saw an aspen tree which stood on the roadside most brilliantly illuminated; every point of the leaves and branches bore a small flame, so that the road could be distinctly seen. The whole phenomenon lasted about three minutes, and a similar emission of light was observed at the same time at a place ten miles distant.

Animal substances, likewise, sometimes emit light under the influence of atmospherical electricity. In the night of January 17, 1817, storms with rain and snow occurred in many places along the east coast of the United States. The flashes of lightning were almost continuous, and but seldom followed by thunder. Several persons who were caught by the storm in the open air and on elevated spots saw the rims of their hats, the seams of their gloves, the ears, the tail and the manes of their horses, surrounded with lively wavering flames of different forms, and producing a crackling noise similar to that which is heard when water is about to boil.

'On May 3, 1821,' says Dr. Allemand in a letter to Professor Pictet, of Geneva,[1] 'I was overtaken while on my way to the village of Motiers, near Neufchâtel, at about ten o'clock at night, by one of the most dreadful thunderstorms imaginable. The night, which had already before been excessively dark, became still more so through the rain that was falling in torrents, and the frequent lightning alone enabled me to see the road. Under these circumstances I suddenly saw a light which seemed to come from above, and raising my eyes I perceived that the rim of my hat was luminous. Believing it to be a real flame, and before I had time to reflect, I quickly passed my hand over it with the intention of extinguishing it, but to my great surprise it appeared more lively than before. I shook my hand, which was dripping with the water that ran from my hat, and saw it shine like a polished metallic surface when reflecting a bright light. I now began to feel a little frightened, and deliberated for a moment whether I should not take refuge in a neighbouring farm; but some knowledge of physical laws, and a most perfect confidence in the Supreme Author of the formidable apparatus which surrounded me, soon induced me to continue my route. Having already, without any evil consequences, filled my hand with the electrical water which shone on the rim of my hat, I now repeated the experiment (though not without some apprehension), to ascertain whether this phosphoric light had any smell, and whether it sparkled or produced a crackling noise.. I, however, remarked no other phenomenon than the beautiful light which did not rise above my hand when I opened it, but seemed to be spread over its surface like a brilliant varnish. Continuing to walk on with my attention continually fixed on the bright aureola of my hat, I now saw vivid rays proceeding from a small plate of metal on the handle of my umbrella. My first movement was again to pass my thumb over it to extinguish this new fire, but the same phenomenon occurred as before, for my hand became as luminous as the metallic plate which it rubbed. All these phenomena ceased as I approached Motiers, and I attributed their cessation to the vicinity of some large poplar trees which border the road near that village.'

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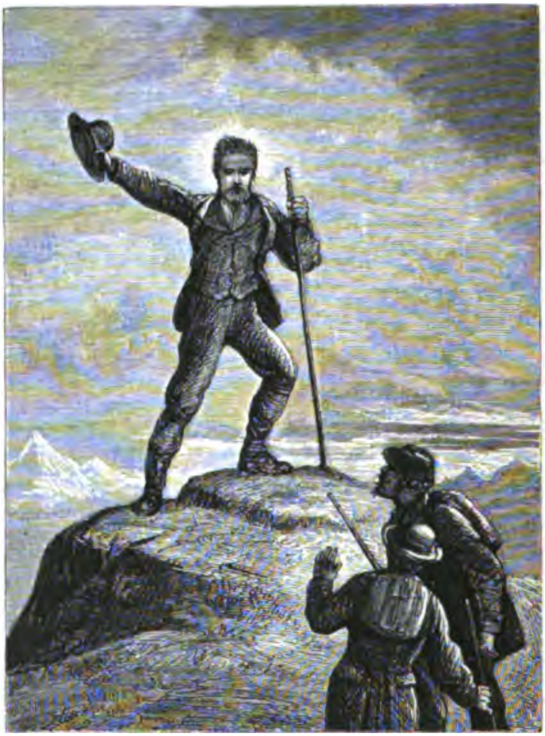
[1] 'Bibliothèque universelle de Genève.'

The summits of high mountains seem frequently to perform the office of conductors, and by the gradual disengagement or outflow of terrestrial electricity in stormy weather to neutralise the positive fluid of the clouds without producing thunder and lightning. M. Henri de Saussure, accompanied by several tourists, had reached the summit of Piz Surley, a mountain 10,000 feet high in the Canton of the Grisons, on June 22, 1867, at about one o'clock in the afternoon. A shower of sleet had fallen, and the party, after leaning their alpenstocks against a rock, were preparing to take some refreshment, when M. de Saussure felt a severe pain in his back like the pricking of needles. 'Supposing,' says the Genevese naturalist, 'that my overcoat contained some pins, I took it off; but far from being relieved I felt the pain increase all over my back, as if a wasp were walking over it and continually stinging me. Quickly taking off my second coat I found nothing that could possibly wound the skin. The pain, which still persisted, now assumed the character of a burn. I now fancied that my woollen shirt had taken fire in some inexplicable manner, and was about to throw off the rest of my clothes when our attention was attracted by a noise resembling the hum of drones. The sounds proceeded from our three alpenstocks, which, leaning against a rock, were loudly singing, emitting tones analogous to those of a kettle in which the water is about to boil. All this might have lasted four or five minutes.

'I understood at once that my painful sensations proceeded from a very intense electrical disengagement which was taking place from the summit of the mountain. Some improvised experiments on our stocks showed us no spark nor appreciable light by day. They vibrated strongly in our hands, and emitted a distinct sound; when held vertically or horizontally, their iron spikes above or below, the vibrations were the same, but no noise proceeded from the ground. The sky was now completely grey, although not uniformly covered with clouds. A few minutes afterwards I felt my hair stand on end, and on raising my hand strong electrical currents flowed from my fingers. In one word, a powerful discharge of electricity was emitted from our stocks, clothes, ears, and hair, and all the prominent parts of our bodies. A single thunderclap was heard far off towards the west. We left the top of the mountain with a certain precipitation, and descended about a hundred metres. As we advanced, the vibrations of our stocks diminished, and we halted when the sound had become so weak that we could only hear it on holding them to our ear.'

The same observer witnessed a similar case of electrical disengagement on visiting a few years later the Nevado de Toluca, in Mexico; but here the phenomenon was still more intense, as might be expected from its taking place under the tropics and at an altitude of 15,000 feet.

In the night of August 11, 1854, while Mr. Blackwell was staying at the Grands Mulets (altitude 3,455 metres) on Mont Blanc, the guide, F. J. Coutlet, stepped out of the cabin at about eleven o'clock at night, and saw light proceeding from the crests of the rocks. He immediately called his companions, who, desirous to ascertain the phenomenon, soon convinced themselves that by an electrical effect produced by the low clouds that were passing over them at the time, the rocky prominences around seemed all on fire. Their own clothes were literally covered with sparks, and



ELECTRIC AUREOLA ROUND HEAD OF TRAVELLER ON MOUNTAIN PEAK.

when they lifted their arms their fingers became phosphorescent.

On July 10, 1863, Mr. Watson, with several other tourists and guides, was visiting the Col of the Jungfrau. The morning had been very fine, but on approaching the Col, the caravan was assailed by a strong wind accompanied with hail. A tremendous thunderclap resounded, and soon after Mr. Watson heard a hissing noise which proceeded from his stock. The sound resembled that of steam violently escaping from a boiling kettle. The company halted, and it was observed that all the stocks and hatchets with which they were provided emitted similar tones. One of the guides now took off his hat, exclaiming that his head was burning. Indeed, his hair stood on end like that of a person electrified by a powerful machine, and every one felt prickings and a sensation of heat in the face and other parts of the body. Mr. Watson's hair stood upright and stiff; the veil which was attached to the hat of another traveller erected itself vertically, and the electrical hissing was heard at the ends of the fingers when moved about in the air. The snow itself emitted a sound analogous to that produced by the fall of a heavy shower of hail. No light was seen, which would certainly have been the case if the phenomenon had happened during the night.

A remarkable electrical disengagement which took place on the summit of the pyramid of Cheops, during the blowing of a Chamsin storm, gave rise to the following entertaining adventure:—'When we had reached the top,' says Professor Werner Siemens, 'we felt a cold sharp wind. The redness of the south-western horizon, which had already been perceptible when we left Cairo early in the morning, had now passed into a colourless haze extending to the zenith, so that instead of enjoying, as we had hoped, an extensive view of the valley of the Nile, we only saw faint outlines of the objects near by. We lay down behind the blocks of stone which are scattered over the platform of the pyramid to rest after the fatigue of ascending, and to avoid the wind, which blew with increasing violence.

'It was interesting to see how the sand of the desert, which, whirled up by the blast, had already covered the plain with an opaque yellow veil, was rising higher and higher along the sides of the pyramid. When it had attained the top, our Arab guides suddenly started up with the exclamation of "Chamsin," and raising their fore-finger to the sky.

'We now heard a peculiar hissing sound, similar to that of the "singing" of water before ebullition. At first we thought that it was a noise made by the Arabs, but I soon became convinced that it also made itself heard when I stood on the highest point of the pyramid and held up my finger. At the same time I felt a slight pricking in the hand on the side exposed to the wind. I could only explain this phenomenon by attributing it to electricity, and my opinion was soon fully confirmed; for, holding up a full wine-bottle, the head of which was coated with tinfoil, I heard the same singing noise as when I held up my finger. At the same time, small sparks were constantly springing from the *etiquette* upon my hand, and on touching the neck of the bottle with my other hand, I felt a severe electric shock, while at the same time a brilliant spark sprang from its metallic coating upon the hand. On wrapping some moist paper round the bottle, the electrical discharge became so strong that I was able to use it soon after as a very effective defensive weapon.

'The Arabs, who for some time had been looking on with astonishment at our proceedings, came to the conclusion that we were practising magic, and insisted upon our leaving the pyramid. Their remonstrances being of no avail, they now wanted to use the right of the stronger, and to make us descend by force. I retreated to the highest stone block, and loaded my bottle as strongly as possible, while the leader of the Arabs seized me by the other hand, and was endeavouring to drag me down. At this critical moment, I touched him with the neck of the bottle, and the effects of the shock it produced were such as to surpass my keenest expectations. The son of the desert, whose nerves had never before felt a similar commotion, fell flat down upon the ground, as if struck by lightning, and then springing up with a dreadful howl, soon vanished out of sight, followed by all his comrades.'

The luminous circle or aureola which has sometimes been seen to shine round a person's head was considered by the ancients as an eminent sign of divine favour. Titus Lucius mentions that the hair of the infant Servius Tullius was found covered with harmless flames while he was sleeping in his cradle, a prodigy which induced Tanaquil, the wife of Tarquin the Elder, to have him educated as her son, and ultimately raised him to the throne. At a much later period, and among a different people, risen on the ruins of Rome, Wamba, a king of the Visigoths of Spain, was likewise supposed to be designed by fate for the crown, on account of a flame that was seen to settle on his head. Virgil poetically attributes the same marvel to the young Ascanius, the forefather of the Julian family; and John of Lydia, probably as great a flatterer as the Court poet of Augustus, adds that a similar prodigy happened to Constantine the Great.

On high towers, or on the vanes of houses, spontaneous jets of flame have not seldom been observed. On January 22, 1778, fiery crests were seen on some of the steeples of Rome; and in 1783 Saussure wrote that on July 22, during a stormy night, he saw a luminous crown encircling a gilt ball at the top of the Church of the Augustines at Avignon.

The rare phenomena of luminous rain, hail, or snow, also belong to the domain of electricity. In 1761 the famous Swedish naturalist Bergmann wrote to the Royal Society of London that he had twice witnessed a rain, unattended by thunder, which emitted sparks as it fell, so that the ground seemed covered with glowing waves.

Luminous snow was seen by Forskall on April 22, 1759, at Upsala, and the same phenomenon occurred on Loch Aire, in Argyleshire, in March 1823; and on January 25, 1822, near Freiberg, in Saxony, when it was witnessed in two different places.

Luminous dust has likewise been observed. During the eruption of Vesuvius in 1794, the extremely fine dust which fell upon the town of Naples emitted a weak but clearly discernible phosphoric gleam. An English gentleman who was at the time in a boat near Torre del Greco, remarked that his hat and those of the sailors, as well as those parts of the sail on which the dust had collected, emitted a similar faint glimmering of light.

With regard to the causes of these various electrical phenomena, whose harmless play forms so remarkable a contrast to the destructive energy of the thunderstorm, the ancients were of course completely in the dark. Pliny the Elder, in one passage of his laborious compilation, remarks that their origin is a 'secret hidden in the majesty of Nature,' but adds soon after that they are of the same kind as the stars that shine in the heavens; and the philosopher Xenophanes, whose idea of the stellar universe was singularly small, believed all stars, these as well as the rest, to be diminutive burning clouds. Metrodorus of Chios, an arrant sceptic, denied their existence altogether, declaring them to be the result of an illusion produced by the fear of the tempest in the eyes, or rather in the imagination of the terrified mariners; but the poet Nonnus came nearer to the truth when calling the flames that sometimes shine on the points of lances 'a powerless image of the lightning.'

For us there can be no doubt that the St. Elmo's fire and all similar phenomena proceed from the same source, and are owing to an excess of free atmospherical electricity. When a thunder-cloud comes very near to the surface of the earth, so that all prominent terrestrial objects are completely dipped in the electrical atmosphere of the cloud, then, instead of an explosive discharge, a noiseless one takes place, manifesting itself in luminous emissions from the tops of masts, the summits of mountains, the tips of spears, and other pointed or prominent objects, particularly when they are good conductors of electricity, such as metals or hair.

Reimarus remarks that the phenomenon generally shows itself after a thunderstorm has spent its force, so that the mariners are perhaps not so much in the wrong who consider the St. Elmo's fire as a favourable omen, or rather as a welcome sign that the danger to which they were exposed is passed. The evident similarity of all these luminous appearances with those that show themselves on points during experiments with the electrical machine fully explains the mode of their formation. In most instances, the luminous emissions are probably caused by the streaming forth of terrestrial electricity to neutralise the electricity of the clouds. In those cases where light has shone forth from a human brow like a crown of glory, we may suppose that eminently nervous individuals are better able to conduct electricity than others of a less susceptible nature, and may thus under certain circumstances be capable of provoking its emission.

CHAPTER XX.

THE IGNIS FATUUS.

Jack o' Lantern—Elf-candles—Gloomy Superstitions—Observations of Dr. Derham, Bessel, Knorr, List, Beccaria, Shaw and others—Enigmas still Unsolved.

ALONG with the shooting stars, the luminous phenomenon known under the name of ignis fatuus is reckoned among the fiery meteors, although its origin is very different, and the only property common to them both is that of shining in the dark. From unknown ethereal heights the shooting stars dart down upon the earth, but the ignis fatuus are the low-born progeny of bogs and stagnant waters.

There is something spectral or ghost-like about their desultory wanderings in the midnight gloom of marshes and burying-grounds, and they thus furnish superstition with ample matter for many a dismal legend. Often have they been taken by the horror-struck wanderer who saw them moving among the tombs for departed spirits unable to find rest in the grave; and in Scotland, where they are called *Elf-candles*, they are supposed to portend the death of some inmate of the house near which they make their fatal appearance. According to another very common belief, they are goblins of a malignant nature, who, by the delusion of a hospitable light, mislead the benighted traveller into some deep morass, where he meets with a miserable end; and it is to this superstitious notion, alluded to by Goldsmith,[1] that the ignis fatuus of the naturalist owes its popular name of Will-with-a-wisp or Jack-with-a-lantern.

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[1] 'Turn, gentle Hermit of the dale,
  And guide my lonely way
To where yon taper cheers the vale
  With hospitable ray.'

'Forbear, my son,' the Hermit cries,
  'To tempt the dangerous gloom;
For yonder faithless phantom flies
  To lure thee to thy doom.'

But though superstition has founded so many wondrous tales on the ignis fatuus, they are a rather uncommon phenomenon, which but few philosophical observers ever had the good fortune to meet with. Dr. Derham happened one night to perceive one of them, and got so near that he could have a very good view of it. This is by no means easy to be obtained, for, among other singularities of the ignis fatuus, it is observed to avoid the approach of any person, and to fly from place to place as if it was animated, and possessed of an instinctive aversion to society. That which the Doctor observed was in some boggy ground betwixt two rocky hills, and the night was dark and calm, by which means probably he was enabled to advance within two or three yards of it. It appeared like a complete body of light without any division, so that he was sure it could not have been occasioned by insects, as some have supposed, the separate lights of which he could not have failed to distinguish, if they had been the cause. The light kept dancing about a dead thistle till a very slight motion of the air, occasioned, as he

IGNIS FATUUS—DISMAL SWAMP.

supposed, by his near approach to it, made it skip to another place, after which it kept flying before him as he advanced.

In a completely dark and wind-still night (December 2, 1807) the celebrated astronomer Bessel saw on a moor in Hanover a great number of small flames of a bluish colour, similar to that of impure hydrogen. Their luminous power was inconsiderable. They often remained immovable, and often to all appearances made horizontal movements. On the spot where they appeared the colonists had dug a quantity of turf, which had rendered the ground uneven, and favoured the collection of water. The flames were not seen on the higher parts of the moor.

Professor Knorr, of Kiew, once saw, while still a student, as he was wandering at night through a swampy country, a very curious ignis fatuus, which, without any of the usual mobility of the phenomenon, continued quietly to shine on the same spot. It glimmered through the leaves of some high reeds, with a bush of alders at its back, so that the light stood as in a green recess. The bush, the reeds, and the grass, were so prettily illuminated as to form a charming picture. The swamp prevented him from coming quite near, but with the assistance of a stick he was able to beat down the rushes, and thus to render the upper part of the little flame completely visible. It was about five inches long and an inch and a half broad. In its centre the light was faint and pale yellow, towards the borders it became more violet, and lost itself in the surrounding darkness without any sharp outlines. The air was quite calm and the light motionless, nor did it exhibit anything like the vivacity of an ordinary flame when the observer agitated the air. He held the point of his stick at least a quarter of an hour over the flame, without perceiving the least trace of heat.

Some very remarkable ignes fatui were observed in October 1859 by Herr List[1] in the valley of the Fulda. A heavy white fog covered the country, and damp mouldy vapours filled the air. The moon was shining through the mist when Herr List saw, scarce two paces before him, a small flame on the roadside. On his advancing towards it, it disappeared, but soon after he saw a new light, followed by several others. All these flames remained fixed on the same spot; to keep them alive he was, however, obliged to approach very carefully, and to avoid causing a draught. They were about the size of a hen's egg, and gleamed, without changing their place, upon and between the blades of grass. They had mostly a greenish-white light. On touching them he found that they emitted no heat. Some of them made their appearance with a crackling noise, such as that which takes place when phosphuretted hydrogen gas explodes spontaneously in the air. The atmosphere was perfectly quiet. Each flame lasted seldom longer than a minute or a minute and a half.

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[1] Poggendorff's 'Annalen,' Band cviii. p. 656.

Beccaria relates that an intelligent gentleman travelling in the evening, between eight and nine, in a mountainous road about ten miles south of Bologna, perceived a light which shone very strangely upon some stones which lay on the banks of the river Rioverde. It seemed to be about two feet above the stones, and not far from the water. In size and form it had the appearance of a parallelopiped, somewhat more than a foot in length, and half a foot high, the longest side being parallel to the horizon. Its light was so strong that it plainly illuminated part of a neighbouring hedge and the water of the river. On wishing to examine it more closely, he was surprised to find that, as he approached, it changed gradually from a bright red, first to a yellowish and then to a pale colour, and when he came to the place itself, it quite vanished. Hereupon he stepped back, and not only saw it again, but found that the farther he receded the stronger and brighter it grew. No smell or any other sign of fire was perceptible.

Dr. Shaw relates in his 'Travels to the Holy Land' that while he was journeying in the valleys of Mount Ephraim an ignis fatuus made its appearance, and attended him and his company for more than an hour. Sometimes it would appear globular, or in the shape of the flame of a candle; at others it would spread to such a degree as to involve the whole company in a pale, inoffensive light, then contract itself, and suddenly disappear, but in less than a minute would appear again; sometimes running swiftly along, it would expand itself at certain intervals over more than two or three acres of the adjacent mountains. The atmosphere from the beginning of the evening had been remarkably thick and hazy.

As the various ignes fatui that have been observed differ so much in character, it is evident that they cannot all be referred to one and the same cause. In many cases they probably proceed from the self-igniting phosphuretted hydrogen gas, which is frequently developed by the putrefaction of organic matter in marshes, moist ground, burying-places, and dunghills, where the phenomenon most frequently appears.

Sometimes vegetable and perhaps also animal substances may in a certain state of decay emit a phosphoric gleam, and give rise to ignes fatui. Thus in 1781 Chladni saw in a garden near Dresden, on a fine summer's evening, soon after a rain, many small luminous bodies hop about in the grass according to the direction of the wind. They were very difficult to catch, and proved on examination to be small gelatinous masses, similar to the spawn of frogs or boiled sago. They had no remarkable smell or taste, and seemed to be mouldering vegetable substances.

Sir Isaac Newton calls the ignis fatuus a vapour shining without heat, and supposes that there is the same difference between this vapour and flame that there is between the shining of rotten wood and burning coals. So much is certain, that there are still many unsolved enigmas in the history of the ignes fatui, and that in this apparently insignificant phenomenon also the veil has not yet been entirely raised which hides from our view the secret laboratories of Nature.

CHAPTER XXI.

HAIL.

Hail always an Unwelcome Phenomenon—Enormous Hailstones—Gross Exaggerations—Sleet and Hail—Hailstorms—Their Disastrous Effects—Unknown in the Tropical Lowlands—Means Suggested as Preservatives against Hail Storms.

IT is only by its prolonged duration, or when it descends in excessive showers, that rain menaces our harvests; it is only when it is driven along on the wings of the storm, or when it rolls its avalanches into the valley, that snow becomes injurious to man; but hail is at all times and under all circumstances an unwelcome phenomenon. No good office can be pleaded in favour of this baneful visitor from the clouds, which so singularly blends the cold of winter with the summer's heat; it never renders any useful service; its constant tendency is damage and devastation. How often has it found a garden and left a waste! how often has it ruined the hopes of the husbandman, and caused him to mourn over his despoiled orchard or his ravaged fields! Even when its missiles are of an ordinary size, hail is one of the most pernicious atmospherical phenomena from the injury it inflicts on tender blossoms or delicate herbs; but when it descends in masses of unusual magnitude no plant is able to resist its violence, and it literally strews the earth with ruins. Halley relates that on April 29, 1697, hailstones fell in Flintshire of the weight of five ounces; and on May 4, of the same year, Robert Taylor[1] found hailstones in Hertfordshire of a circumference of fourteen inches. The famous Volta assures us that among the hailstones which devastated the town of Como and its environs on August 20, 1787, some were found which weighed nine ounces; and we are informed on newspaper authority that the hailstones which on June 9, 1822, broke the tiles of numerous roofs in the town of Trente in Tyrol weighed from eight to sixteen ounces. During a terrible hailstorm which burst over the Orcadian island of Stronsa in the year 1818, Stewart[1] relates that stones fell of the size of a goose's egg, which broke even wooden window frames to pieces. The weight of the largest of these atmospherical projectiles was estimated at half a pound, and some had penetrated to a depth of four inches into the soil. A boy was wounded so severely in the neck that after several months he had not yet quite recovered; the horses and cows which had been overtaken by the storm in the open air were all more or less severely injured and bleeding; the sea drifted many killed birds to the shore, and a great number were found dead upon the ground. Some of the younger horses were so terrified or hurt that they lay prostrate in a state of stupefaction, and never regained their former activity and strength.

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[1] Arago, 'Annuaire pour 1829.'

After a hailstorm of extraordinary violence which was observed by Professor Muncke[2] in Hanover in 1801, a great number of hares, partridges, crows, and sparrows, were found dead in the fields; and persons who had been surprised by the hail in the open air were covered with bruises and contusions.

On arriving at the foot of the Sierra Tapalguen, in the pampas of Buenos Ayres, Mr. Darwin[3] was told a fact which he would not have credited if he had not had partly ocular proof of it, namely, that during the previous night, hail as large as small apples, and extremely hard, had fallen with such violence as to kill the greater number of the wild animals. One of the men of the posta had already found thirteen deer (*Cervus campestris*) lying dead, and Mr. Darwin saw their *fresh* hides; another of the party, a few minutes after his arrival, brought in seven more. The men believed they had seen about fifteen dead ostriches (part of one of which was served for dinner), and they said that several were running about evidently blind in one eye. Numbers of smaller birds, as ducks, hawks, and partridges, were killed. One of the latter had a black mark on its back, as if it had been struck with a paving-stone. A fence of thistle stalks round the hovel was nearly broken down, and a man putting his head out to see what was the matter, received a severe cut, and now wore a bandage. 'The storm,' adds Mr. Darwin, 'was said to have been of limited extent; we certainly saw, from our last night's bivouac, a dense cloud and lightning in this direction. It is marvellous how such strong animals as deer could thus have been killed; but I have no doubt, from the evidence I have given, that the story is not in the least exaggerated. I am glad, however, to have its credibility supported by the Jesuit Dobrizhofer, who, speaking of a country much to the northward, says, "hail fell of an enormous size, and killed vast numbers of cattle; the Indians hence called the place Lalegraicavalca, meaning 'the little white things.'" Dr. Malcolmson also informs me that he witnessed in 1831, in India, a hailstorm which killed numbers of large birds, and much injured the cattle. These hailstones were flat; one was ten inches in circumference, and another weighed two ounces. They ploughed up a gravel walk like musket balls, and passed through glass windows, making round holes, but not cracking them.'

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[1] 'Edinburgh Philosophical Journal,' No. viii. p. 365.

[2] Gehler's 'Physicalisches Wörterbuch,' Artikel *Hagel*.

[3] 'Journal of Researches.'

Many other instances of unusually large hailstones of the size of a goose's egg, and the weight of half a pound or even more, might be cited on unquestionable authority; but when we are told that hailstones weighing six or even eight pounds fell in 1719 near Namur, we do well to hesitate before we believe the truth of this account, or at least to think it more probable that several stones after falling may have frozen into one mass, and thus deceived superficial observers. As for the stupendous block of ice resisting the efforts of eight men to move it, and of the computed weight of 1,100 pounds, which is said to have fallen on May 8, 1802, near a Hungarian village called Putzemischel, we may at once pronounce it a gross fable, as well as the story of the iceblock of the size of an elephant, which we are told dropped from the clouds near Seringapatam during the reign of Tippoo Sahib. We must also be excused from putting implicit faith in the 'Chronicle of Rheims,' when it informs us that on June 24, 823, a mass of ice fell from the skies fifteen feet across and six feet thick; or from fully believing the Missionary Father Huc, who mentions somewhere that during a dreadful storm which he witnessed in Tartary in 1843, an iceblock of the size of a millstone dropped from the skies near to his dwelling, and though the weather was very warm, took three full days before it melted.

During inconstant weather, in winter and spring, when storms alternate with sunshine, the fall of sleet is a not unfrequent phenomenon. In Central Europe it more commonly takes place in the months of April and May accompanied by rain or snow; in England, during the winter. Electrical discharges are seldom observed during the fall of sleet. Its formation is ascribed to the compression of snow flakes, which, in consequence of a rotatory movement given them by the wind, acquire a globular shape.

Sleet is generally milk-white and opaque; but when it falls along with rain it is sometimes covered with a thin coat of ice, and forms a transition to the far more formidable phenomenon of hail. Its pellets are very minute, having at the most a diameter of from one to two lines.

Hail is distinguished from sleet both by its larger size, its greater hardness, and its transparency, as it chiefly consists of a shell of ice enveloping a nucleus of snow. In some rare cases, hard substances, such as grains of sand, volcanic ashes, or chaff, have been found in the interior of hailstones. It can hardly be doubted that these substances were floating in the atmosphere at the time when the hailstorm was forming, and served as points of crystallisation to the congealing moisture of the air.

The chief characters which distinguish hailstorms from ordinary thunderstorms are the peculiar rattling noise which precedes the fall of the hailstones, the whitish colour of the cloud-stripe in which the latter are formed, and a darkness which Tessier compares to that which is occasioned by a total eclipse of the sun. According to Professor Muncke's observations, single flashes of lightning and abrupt thunderclaps are not so common at the beginning of a hailstorm as a continual discharge of electric light and an uninterrupted rolling of thunder. After a thunder-cloud has rained for some time, the danger of a destructive hailfall is generally past. In most cases hailstorms begin with the phenomena above described; a thunderclap of surpassing violence ensues, then follow single heavy drops of rain, succeeded by single small hailstones, and by the pelting hard shower which, with short periods of intermittence, and accompanied with thunder and lightning, generally lasts but a few minutes. The darkness, the noise in the air, the thunder and lightning, the rattling of the hailstones on the pavement and the roofs, the breaking of windows, all combine to form one of the most terrific scenes in Nature.

The quantity of hail falling during one of these storms is frequently very considerable. After the hailstorm, which on July 24, 1818, burst over Stronsa,[1] it was found lying nine inches deep in the open fields. During two very severe hailstorms which he witnessed in Hanover (1801) and Heidelberg (1824), Professor Muncke had an opportunity of observing its fall over a wide horizontal space. In Hanover, where the temperature fell very considerably, it lay three inches deep; in Heidelberg not quite an inch and a half. In his opinion, six inches is the maximum height of a hailfall in Germany. An exact measurement is, of course, impossible, as hail is generally accompanied by a heavy rain, which floats it along, and causes it to accumulate in some places more than in others.

The sudden melting of large masses of hail has been known to occasion the most disastrous floods. Villaret relates that in the year 1360, the inundation caused by a hailstorm killed a thousand men and more than six thousand horses in the English camp at Brétigny. Should this account be deemed exaggerated, it is perfectly authentic that during a terrific hailstorm which befell the small town of Beverungen in Hanover, the floods, consisting of hail and water which rushed down a sloping eminence, overturned a heavy cart drawn by four horses, and swept it along with them into the Weser. The torrent rushed with such impetuosity into the small town that it blocked the gates at the opposite end by raising an ice dam before them, and inundated the streets. In the year 1800, an insignificant brook at Mariengarten, near Göttingen, was so enormously swollen by a sudden influx of hail and water that it swept away a garden wall six feet high and two feet thick, which opposed its course, and very nearly caused a large massive house to fall in.

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[1] 'Edinburgh Philosophical Journal,' No. viii. p. 366.

Fortunately, hailstorms generally confine their devastations to a limited extent of country, as their width rarely exceeds from 1,000 to 3,000 feet, and their length five or ten miles. Their destructive power is also not alike over the whole width of the hail-cloud, being generally much less along its borders than towards the centre.

Sometimes, however, a hailfall has been known to sweep like a scourge over whole provinces; as, for instance, the dreadful storm which on July 13, 1788, covered a great part of France and Belgium with desolation, and carried its ravages even as far as Germany. Beginning at the Pyrenees it only terminated on the shores of the Baltic. It extended simultaneously in two parallel stripes, varying in width from seven to twelve miles, and separated by an intermediate space of an average width of fifteen miles, where it merely rained. The general direction of these stripes was from Amboise to Malines, and from the confluence of the Indre and the Loire to Geneva. Everywhere darkness preceded the hail, and extended with heavy rains over a far wider space. The storm advanced with a rapidity of thirty-eight miles in an hour, and the hailfall never lasted longer than seven or eight minutes in one place. The hailstones were partly rounded, partly angular, the heaviest weighing about half a pound. In France alone, 1,039 parishes were devastated by the hail, and the damage which it caused was officially estimated at 24,690,000 livres, or a million of pounds.

Under the name of the Thuringian deluge, the terrible hailfall was long remembered which on May 29, 1613, devastated almost the whole of the country from Mühlhausen to the valley of the Saal, and from the foot of the Thuringian Forest to that of the Hartz Mountains. The masses of hail and rain were so immense that all the rivers overflowed their banks, converting wide plains into lakes; almost all the bridges and many houses were destroyed, and more than sixty persons, with a far greater number of cattle, perished in the floods. The hailstorm which occurred in Wurtemberg in 1873 extended its ravages over 188,225 acres of land, and caused a loss of 7,452,000 florins.

A fall of aerolites is more common in our latitude than a fall of hail in the tropical regions at elevations less than 1,800 feet above the level of the sea, in spite of the frequent thunderstorms of the equatorial zone. A hailstorm, mentioned by Father Roman as having occurred at Pararuma on the Orinoco about the middle of last century, is almost the only instance on record, and it still remains to be explained why it often hails at Montpellier, Philadelphia, and Rome, during the tropical heat of the summer months, and not at all in the lowlands of Brazil or Guiana. In the higher mountainous regions of the equatorial zone hail is not unusual.

In Cumana, hail has never been heard of; but in Caraccas, which is about 1,200 feet higher, a hailstorm takes place every four or five years. Humboldt mentions a hailstorm on the Chimborazo at a height of 17,400 feet, and hail has been often observed in the Abyssinian mountains and the East Indian highlands.

In the temperate regions, on the contrary, hail is more frequent in the lowlands than in mountainous countries. In Cressier, near the Lake of Neufchâtel, the vineyards are often damaged by hail; while at Lignières, situated 1,200 feet higher on the slope of the Chaumont, hail falls very rarely. In the high valley of Travers it rains at the time when hailstorms burst over the mountain slopes situated lower down; and, to add but one more instance, hailstorms are very rare near Clermont, in Auvergne, between the Mont d'Or and the Puy de Dôme, and by no means uncommon in the neighbouring and less elevated villages.

It is a well-known fact that some localities are particularly exposed to hail showers, while others seem to be completely exempt from them. According to observations made by De Saussure,[1] in plains situated at the foot of high mountains hail falls more frequently and heavily at a certain distance from the latter than either farther on or closer by. Where the valleys of the Alps emerge from the steep rock walls which enclosed them, the plain generally spreads out in hills which, in comparison to the previous narrow gorges, appear flat. Such plains in the vicinity of high mountains are almost yearly struck by hail.

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[1] 'Voyages,' vol. iv. p. 162.

That the local appearance of hail is often determined by apparently insignificant circumstances is shown very plainly by the village of Casalbero, in the former kingdom of Naples. The place was completely free from hail as long as a high hill situated to the north-west was covered with woods. But since the trees have been felled to make way for the plough, hail falls almost every year.

Hailstorms are more frequent in some years than in others. In general, the warmest and finest summers are also the most dangerous with regard to the ravages caused by hail. Sometimes the same localities are devastated for several successive years by hail, and then again spared for a long time, in consequence of unknown atmospherical circumstances, which our ignorance is fain to term capricious.

Hailstorms are most frequent in summer; while sleet, which is a far more common phenomenon in England, belongs to the colder months of the year. The heavy hailstorm which befel Montpellier on January 30, 1741, was a remarkable exception from the general rule. Hailstorms are not confined to certain hours of the day; they are, however, more frequent in the afternoon than in the forenoon, and rarely take place at night.

Hail is beyond all doubt one of the most enigmatical atmospherical phenomena, as it is one of the most destructive. No meteorologist has yet been able to explain in a perfectly satisfactory manner how hailstones of such considerable size are able to form in the clouds in so short a time, and often during the most sultry weather. On Volta's theory, the hailstones are successively attracted by two clouds charged with opposite electricities, and thus grow until they fall; but if the hailstones were thus attracted, it seems much more probable that the two clouds would be mutually attracted, and would unite.

The sudden irruption of cold air streams into a hot atmosphere charged with aqueous vapour, or the rarefaction and consequent refrigeration of the air produced by rotatory winds, have likewise been called in to explain the mysteries of hail; but the most sagacious theories have hitherto found more opponents than adherents, and not one of them is free from serious objections. Evidently there are influences at work in the clouds which we are not yet able to measure, and the causes of many of the revolutions of which they are the scene are still as unknown to us as they were to the philosophers of ancient times.

The various means suggested to avert the disastrous effects of hail have been as unsuccessful as the efforts to explain its origin. By the noise of bells and drums, by the firing of cannon, by the shooting of rockets, by great fires on the mountains, attempts have been made to avert the danger, but all these preservatives have proved as ineffectual as the consecrated herbs or magic formulas with which superstition has on other occasions taken the field against it.

From the intimate connexion between hail and thunderstorms the idea naturally arose to deprive the clouds of their electricity by erecting a number of lightning conductors in the fields, and thus rendering the formation of hail impossible. This idea found at first a great number of adherents, particularly in the Canton de Vaud, in Switzerland, where many vineyards were consequently provided with this new means of protection. But by a strange irony of fate, a terrible hail shower fell in the night, from the 22nd to the 23rd June, 1826, upon the protected vineyards, and left not a grape standing, while other unprotected vineyards in the vicinity remained untouched.

CHAPTER XXII.

AEROLITES AND SHOOTING STARS.

Shooting Stars—Periodical Recurrence of Large Falls of Shooting Stars—Phenomena—Fire Balls—Aerolites Worshipped in Ancient Times—The God of Emesa—Heliogabalus—The Ancile or Sacred Shield of Numa—The Stone of Aigos Potamos—The Stone of Ensisheim—Scientific Errors—Chladni—Frequent Occurrence of Aerolites—Dr. Livingstone—Persons Killed by the Fall of Aerolites—Their Chemical Composition—Their Origin—Their Connexion with Comets—Their Importance in the History of Civilisation.

WHILE fixing his gaze on the starry heavens the observer is not seldom surprised by an equally beautiful and striking phenomenon. For motion and disturbance suddenly arise in the usually so quiet picture of the nocturnal sky; a star seems to detach itself from the firmament, and rapidly shoots through the air, to disappear after a momentary blaze

The phenomenon is far from being rare, for single shooting stars may be seen almost every night; but sometimes they appear in such astonishing numbers as to have been found worthy of record in the annals of past ages.

Thus, according to Arabian historians, on the night of the death of King Ibrahim ben Ahmed, in October 902, a great fall of shooting stars took place, which were described as resembling a 'rain of fire,' and supposed to have some prophetic or sympathetic connexion with the potentate's decease.

On the night of April 25, 1095, it was recorded that in France the stars were seen 'falling from heaven as thick as hail' by innumerable witnesses; and here again superstition, true to her usual practice of bringing the great phenomena of Nature into relation with human affairs, drew her own

SHOWER OF SHOOTING STARS.

inferences from the splendid sight, for at the Council of Clermont it was mentioned as foreboding the great movement of the Crusades.

In modern times, similar 'rains of fire' have been observed, but science has drawn conclusions from their appearance very different from those which found credit in the dark mediæval ages.

During their stay at Cumana, Humboldt and Bonpland witnessed a most extraordinary fall of meteorites, which took place on the morning of November 12, 1799. During four hours the whole sky was constantly filled with shooting stars and fiery balls, most of them leaving long trains of light behind them as they fell. The wonderful phenomenon which filled the great naturalist with delight was seen at the same time at Nain in Labrador, at Lichtenau in Greenland, and at Itterstadt in the Grand Duchy of Weimar. The Esquimaux in Davis Straits were struck with terror at the sight, while the astronomers of Karlsruhe and Halle were carefully examining it. In those times attention had not yet been directed to the periodical return of large showers of meteors; but on the night of November 12, 1822, shooting stars mingled with balls of fire were seen in vast numbers at Potsdam. Again, on the night of November 13, 1831, Captain Berard, of the French navy, commanding the brig 'Le Loiret,' saw, off the Spanish coast, a prodigious number of shooting stars darting through the atmosphere from four till seven in the morning; and in the following year, at the same date and almost at the same hour, an incredible number was seen in Germany, Switzerland, Austria, and South Russia. On the Lower Rhine they darted through the skies in all directions; and at Suczowa, in the Bukowina, they were described as forming a fiery shower. According to several observers, some of them fell upon the ice, where they burst to pieces with a loud crash, and the emission of sparks.

On the night of November 12–13, 1833, showers of stars of unexampled magnificence took place in the United States. The meteors began to attract notice by their frequency as early as nine o'clock on the evening of November 12; the exhibition became strikingly brilliant about eleven o'clock, but most splendid of all about four o'clock, and continued with but little intermission until darkness merged in the light of day. A few large fire-balls were seen even after the sun had risen. The entire extent of the exhibition is not ascertained, but it covered no inconsiderable portion of the earth's surface. It has been traced from the longitude of 61° in the Atlantic Ocean to longitude of 100° in Central Mexico, and from the North American lakes to the southern side of the island of Jamaica. Everywhere within these limits the first appearance was that of fireworks of the most imposing grandeur covering the entire vault of heaven with myriads of fire-balls resembling sky-rockets.

On more attentive inspection it was seen that the meteors exhibited three distinct varieties: the first consisting of *phosphoric lines*, apparently described by a point; the second of *large fire-balls* that at intervals darted along the sky, leaving numerous trains, which occasionally remained in view for a number of minutes, and in some cases for half an hour and more; the third of undefined *luminous bodies*, which remained nearly stationary for a long time.

One of the most remarkable circumstances attending this extraordinary display was that the meteors all seemed to emanate from one and the same point, which was observed by those who fixed its position among the stars to be in the constellation Leo. This point remained stationary among the stars during the whole period of observation, that is to say, it did not move along with the earth in its diurnal rotation eastward, but accompanied the stars in their apparent progress westward. It is not certain whether the meteors were in general accompanied by any peculiar sound. A few observers reported that they heard a hissing noise like the rushing of a sky-rocket, and slight explosions like the bursting of the same bodies. Nor does it appear that any substance reached the ground which could be clearly established to be a residuum or deposit from the meteors.

Attempts were made to obtain at least some approximation to the number of shooting stars which appeared on this occasion. At the time when they fell most thickly an observer at Boston estimated them at about half the number of the flakes which would be presented by a dense snowstorm, and inferred that on this memorable night at least 300,000 meteors must have passed through that part of the terrestrial atmosphere which was visible in that city.

The phenomenon has since then never again appeared on so magnificent a scale, but still so conspicuously that the periodical appearance of unusually large showers of shooting stars about November 12 cannot possibly be doubted, although it does not annually recur in the same countries.

In 1836 both Olbers and Quetelet drew attention to the fact that shooting stars had often been observed to fall in unusual numbers about August 10, and that their periodical recurrence might probably be expected about this time. Their surmise was confirmed as early as the following year; and since then the phenomenon long known in England under the popular name of 'St. Lawrence's fiery tears' has been annually observed, although not always with the same intensity.

This period generally comprises the days from the 7th till the 13th of August. The appearance of shooting stars in large numbers may also be looked for at the dates of April 22–25, July 17, November 27–29, and December 6–12; but single ones, as I have already mentioned, probably make their appearance every night, so that an attentive observer can on an average count from five to eight of them in an hour.

In the year 1798 an investigation of the heights of shooting stars was undertaken by Brandes at Leipzig and Benzenberg at Dusseldorf. Having selected a base line (about nine miles in length), they placed themselves at its extremities on appointed nights, and observed all the shooting stars which appeared, tracing their courses through the heavens on a celestial map, and noting the instants of their appearances and extinctions by chronometers previously compared. Similar sets of observations which have since been repeated lead to the conclusion that the heights of the shooting stars above the ground vary from 6 to 550 English miles, that they move with a velocity of between 18 and 220 miles in a second, and that their trajections are frequently not straight lines, but incurvated, sometimes in the horizontal and sometimes in the vertical direction. A remarkable fact, particularly important, as will be seen on reference to their physical theory, is that the predominant direction of their motion is contrary to that of the earth in its orbit.

It may be asked, how the evolution of light can take place at altitudes so far surpassing the probable bounds of the atmosphere, or where, supposing air to exist, it must necessarily be so attenuated as to approach the limits of absolute vacuity?

LARGE FIERY METEOR DARTING THROUGH SKY.

Poisson, the eminent French geometer, has endeavoured to solve the question by affirming the probability of an atmosphere of electricity surrounding the earth and lying above the atmosphere of air. He supposed that the meteorite rushing through this electric atmosphere would decompose the electric fluid exactly as the friction of an electric machine decomposes it between the cushion and the glass, and that by such electric decomposition light and heat would be evolved.

In all probability, the smallest shooting stars which traverse the sky as mere phosphoric lines are identical in nature with the largest fire-balls, as innumerable gradations of size occur between them, and their heights, their velocities, and the direction of their motion, are alike.

The fire-balls often show themselves in the following manner:—A small and dark cloud is observed to be suddenly formed in a perfectly clear sky, and soon after to ignite, giving birth to a fiery ball, which darts with immense rapidity through the skies, and is followed by a long train of flame and smoke. Finally, a dreadful explosion takes place, particularly if the phenomenon is attended with a shower of stones. The noise which attended the fall of aerolites at Aigle, in Normandy, was heard over a space the radius of which was estimated at thirty leagues; it resembled the discharge of artillery, followed by salvos of musketry, and is said to have lasted from five to six minutes. In cases where no explosion took place, the fiery meteor did not descend upon the earth, and continued its course through space, or else it was too distant to be heard.

Fire-balls have been observed whose computed diameters vary from 500 to 2,600 feet. The fire-ball seen at Weston, in Connecticut, on December 14, 1807, measured 500 feet. Le Roi observed one on July 10, 1771, which measured about 1,000 feet; and Sir Charles Blagden estimated the diameter of one observed by him on January 18, 1713, at 2,600 feet. These measurements include, however, not only the solid mass, but the igneous matter by which it may have been surrounded.

Fire-balls are sometimes seen over an immense extent of country. One of these fiery meteors which made its appearance on March 31, 1776, was visible all over Italy, and the greatest part of Germany. On October 14, 1863, at three in the morning, a splendid fire-ball was observed by Mr. Schmidt, director of the observatory in Athens. It made its first appearance as a shooting star, but soon surpassed Sirius in splendour, glowing with a bright yellow colour. It moved through the constellation of Eridanus towards the east, spreading so brilliant a light as to obscure the stars; the town of Athens, the country, and the sea, all seemed as if illuminated by an enormous fire. The darker masses of the Acropolis and the Parthenon stood forth from a background of golden green. Seen through a telescope the meteor appeared not as one luminous body, but in the form of two yellow-green fire-balls like elongated drops, the largest foremost, and followed by a red stripe, in which smaller luminous masses were scattered like sparks. At the moment of its disappearance the meteor seemed divided into four or five dark red fragments. No noise was heard.

The luminous train which usually follows the shooting stars and fire-balls gives rise to the question whether this be a real continued physical line of light, or whether it must not rather be ascribed to the same cause which makes us see a complete circle of light when a lighted stick revolves rapidly in a circle. In this case, the circle of light is not real, the effect being an optical illusion. The membrane of the eye, which is affected by light, has been ascertained to preserve the impression made upon it for about one-tenth of a second after the cause which produced that impression has ceased to act. But in the case of fire-balls the trains are sometimes seen for several minutes, so that their actual material existence cannot be doubted.

Dr. Livingstone mentions a splendid meteor which occurred during his stay at Motunta, and was observed to lighten the whole heavens. His back was turned to it, but, on looking round, the streak of light was seen to remain in its path some seconds. The impression was evidently not a mere optical effect of the rapid motion of the fire-ball; for in this case the meteor was not actually seen, and yet the streak was clearly perceived. Various explanations have been offered of these luminous trains, which probably consist of smaller particles detached by combustion from the main body.

The aerolites or stones which, after the explosion of a fire-ball, drop down upon the earth like the fragments of a bomb, are worthy of notice in the long history of human errors. The ancients never doubted that they were precipitated from the skies, and so far they were right; but they were as decidedly wrong in paying them divine honours on account of their celestial origin.

In Phrygia, Cybele, the mother of the gods, was revered under the form of a meteorolite. An oracle which announced that if the sacred image were transported from Asia Minor to Rome no enemy who ventured to approach the capital of the world would escape perdition, induced the Romans to transfer the black stone from Pessinus to the great city in the year 203 B.C., and to erect a temple for its reception on the Palatine Hill. At present it would only find a probably unnoticed place in the obscure corner of a museum.

At Emesa, in Syria, the sun was likewise adored under the form of a black stone fallen from heaven. The Roman emperor Heliogabalus, who had begun his career as a priest in the temple where it was worshipped, ascribed his elevation to the throne to this protecting deity. The triumph of the god of Emesa over all the religions of the earth was the great object of his zeal and vanity, and the pompous display of his superstitious gratitude the only serious occupation of his short and inglorious reign. 'In a solemn procession through the streets of Rome the way was strewed with gold dust; the black stone set in precious gems was placed on a chariot drawn by six milk-white horses richly caparisoned. The pious emperor held the reins, and, supported by his ministers, moved slowly backwards that he might perpetually enjoy the felicity of the divine presence. In a magnificent temple raised on the Palatine Mount the sacrifices of the god were celebrated with every circumstance of cost and solemnity. The richest wines, the most extraordinary victims, and the rarest aromatics, were profusely consumed on his altar. Around the altar a chorus of Syrian damsels performed their lascivious dances to the sound of barbarian music, whilst the gravest personages of the state and army, clothed in long Phœnician tunics, officiated in the meanest functions with affected zeal and secret indignation.'[1] It is probable that, with the assassination of the miserable wretch who disgraced the imperial name, the honours paid to his favourite stone likewise ceased, for we find no further account in history of the god of Emesa.

One of the sacred objects most highly venerated in ancient Rome was the Ancile or sacred shield of Numa—a stone fallen from heaven under the reign of that pious king. The nymph Egeria and the Muses had attached the welfare of the city to its possession, and it was consequently preserved as a sacred pledge in a sanctuary on the Palatine or Capitoline Hill. Mamurius Veturia was ordered to fabricate eleven other precisely similar shields, so as to prevent the real one from being found out and purloined. Once a year these twelve shields were carried in solemn procession through the town by the Salians or priests of Mars. What may have become of the formerly so venerated Ancile when the old gods gave way to a new creed? Was it cast into the street like a vulgar stone, or did some zealot shiver it to pieces? And where, after many transformations, may the atoms which once composed it now be scattered?

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[1] Gibbon's 'Decline and Fall of the Roman Empire,' vol. i. chap. vi.

For a knowledge of the oldest well-authenticated meteoric stone-falls we are indebted to the Chinese. There exist in the Celestial Empire catalogues of the remarkable meteors of all classes, aerolites included, which have appeared there since the year 644 B.C.; for, at a time when barbarous hordes still roamed on the borders of the Thames or of the Rhine, the phenomena of Nature were attentively noted on the banks of the Yellow River. To give an idea of the minuteness of these records, it is enough to mention that in the three centuries, from A.D. 960 to 1270, no less than 1,479 meteors were registered by the Chinese observers officially appointed for this purpose.

Among the various instances recorded in ancient history, that of a shower of stones on Mount Alba, in the reign of Tullus Hostilius, is the oldest mentioned in the annals of Rome. When the Senate were told that it had rained stones they doubted the fact, and deputed commissioners (probably the first instance of a parliamentary inquiry) to investigate the particulars of the case. They were then told that stones had really fallen, as when the wind drives a mass of hail upon the earth. On this occasion, Livy mentions a decree of the Senate that, whenever a similar prodigy should occur, it was to be celebrated by a nine days' festival.

But the most remarkable and authentic record of antiquity is that of the massive stone which fell in the 78th Olympiad (about the time of the birth of Socrates) at Aigos Potamos, or Goat's River, on the Hellespont; the place which soon after was to be rendered still more famous by the naval victory of Lysander, which for a time subjected Athens and Greece to the Spartan power. Pliny assures us that this extraordinary mass was as large as a cart, and of a burnt colour; and both he and Plutarch mention that in their times, that is, in the sixth century after its fall, the inhabitants of the Chersonesus still held the Thracian stone in great veneration, and exhibited it as a public show. It has been well remarked[1] that if this extraordinary aerolite remained visible and of such magnitude as described down to Pliny's time, it is far from impossible that it may even now be re-discovered—with the aid, perchance, of some stray tradition attached to the place surviving, as often happens, the lapse of ages, the changes of human dominion, and even the change of race itself on the spot. The research would well reward a traveller's trouble; for, if successful, it would be of interest enough both for history and science to perpetuate a man's name.

The whole period of the middle ages gives us but vague and scanty information on the subject of meteorites; but towards the close of the fifteenth century the fall of the celebrated stone of Ensisheim is distinctly and circumstantially described by the chronicler of the time. The following *naïve* account accompanied this very singular mass when it was suspended in the church:—'In the year of the Lord, 1492, on Wednesday, which was Martinmas Eve, the 7th of November, there happened a singular miracle; for between eleven o'clock and noon there was a loud peal of thunder and a prolonged confused noise, which was heard to a great distance, and a stone fell from the air in the jurisdiction of Ensisheim, which weighed 260 pounds; and the confused noise was, moreover, much louder than here. There a child saw it strike on a field, situated in the upper jurisdiction, towards the Rhine and Inn, near the district of Gisgard, which was sown with wheat, and did it no harm, except that it made a hole there; and then they conveyed it from that spot, and many pieces were broken from it which the landvogt forbade. They therefore caused it to be placed in the church, with the intention of suspending it as a miracle, and many people came hither to see this stone. So there were remarkable conversations about it, but the learned said that they knew not what it was; for it was beyond the ordinary course of nature that such a large mass should smite the earth from the height of the air, but that it was really a miracle of God; for before that time never anything was heard like it, nor seen, nor described. When the people found that stone, it had entered into the earth to the depth of a man's stature, which everybody explained to be the will of God that it should be found; and the noise of it was heard at Lucerne, at Villing, and in many other places, so loud that it was believed that houses had been overturned. And as the king (Maximilian) was here the Monday after St. Catherine's Day of the same year, his royal excellence ordered the stone which had fallen to be brought to the castle, and, after having conversed a long time about it with the noblemen, he said the people of Ensisheim should take it, and order it to be hung up in the church, and not allow anybody to take anything from it. However, his excellency took two pieces of it, of which he kept one, and sent the other to the Duke Sigismund of Austria, and they spoke a great deal about this stone, which they suspended in the choir, where it still is, and a great many people came to see it.' It may be added that the Ensisheim stone was transferred during the first French revolution to the national library at Colmar, and notwithstanding numerous dilapidations still weighs 150 pounds.

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[1] 'Quarterly Review,' No. clxxxiii. p. 81.

Though instances of falling stones were continually occurring in France, England, Germany, Italy, and elsewhere, though the celebrated Gassendi related that on November 27, 1627, about ten o'clock A.M., he himself saw a flaming stone fall on Mount Vaision in Provence, that its fall was accompanied by a loud noise like the discharge of artillery, and that it weighed fifty-nine pounds, yet the learned academies of the last century, as mistaken in their arrogant incredulity as the over-credulous ancients who paid divine honours to stones dropped from heaven, obstinately rejected their origin from on high as fabulous.

Meanwhile, meteorites were every now and then dropping from the skies to the great amazement and terror of the unlearned, who actually saw them fall; as, for instance, at Jouillac in France, where on July 24, 1790, a large meteor exploded in the air with a terrific noise, scattering at the same time a shower of stones upon the earth. Had such a striking proof fallen on the green baize of an academical table while the learned gentlemen were assembled around it, they would probably have been convinced by ocular demonstration, except perhaps the incorrigible meteorologist De Luc, who boldly asserted that even if a stone were to fall at his feet from heaven, he would not believe it.

The merit of having been the first to bid defiance to the scientific prejudices of his time is due to the German philosopher Chladni, who in the year 1794 published a catalogue of all the authentic instances of aerolites, and boldly asserted their extraterranean origin. As if the skies had been desirous to corroborate his opinion, a remarkable fall of meteorolites took place at Sienna, on January 16, 1794, soon after the publication of his treatise; but still the wise men of London and Paris smiled contemptuously at the imbecile German who ventured to bring ridiculous nursery tales before the venerable forum of science.

The stone which fell at Wold Cottage in Yorkshire in 1795 at length turned the tide in his favour. Its fall was seen by two persons, following an explosion in the air. It had penetrated to a depth of eighteen inches in the soil and chalk whence it was taken. It weighed about fifty-six pounds.

A numerous shower of stones at Benares, on the Ganges, on December 13, 1798, afforded additional and conclusive evidence, as the fact was both fully established by the official investigations of Messrs. Davis and Erskine, the judge and assistant collector of the district, and the composition of the meteorolites collected on the spot found by Mr. Howard, whose analysis of it was published in the 'Philosophical Transactions' for 1802, to be identical with those of Wold Cottage. Yet when Pictet, who had just come from England, read a paper to the French Institute on this subject, he met with so much incredulity in that learned body that he needed a certain degree of courage to finish his communication. At length the question was fully settled by the great fall of stones - 2,000 or 3,000 in number—which occurred near L'Aigle, in Normandy, on April 26, 1803. The famous physicist, Biot, was deputed by government to repair to the spot, where his minute investigation fully ascertained the fact, and led to the final conversion of even the most obdurate sceptics. Thus the meteorolites, so long an object of ridicule to the over-wise, at length found their due place in natural history.

Who would believe that a phenomenon which, not a century since, was treated as a fable by all the learned in Europe, is of such frequent occurrence that probably not a day passes on which a meteorolite does *not* fall in some part of the earth?

That this is by no means an exaggeration may be inferred from the fact that from the year 1800 to 1854, 115 meteoric stone-falls, or about two annually, are known to have taken place.[1] But a much larger number remained beyond all doubt wholly unnoticed, for how many meteorolites may not have fallen upon heaths, forests, or mountains, or during the night? Besides, the civilised or half-civilised countries where the above-mentioned stone-falls have been recorded form but a very small part of the earth's surface, when compared with the vast regions peopled by barbarians or savages, and still more with the immensity of the sea. Hence von Reichenbach[2] estimates the annual number of meteoric stone-falls at no less than 4,500, or at twelve daily for the whole surface of the earth.

Dr. Livingstone witnessed the fall of aerolites on no less than three different occasions, which may be also adduced as a proof of the frequency of the phenomenon. 'Possibly,' says the illustrious traveller, 'the passage of a few such aerolites through the atmosphere to the earth by day may occasion the phenomenon of thunder without clouds.'

From the frequent fall of aerolites it might naturally be expected that buildings must sometimes be damaged, or even persons killed, by the fall of meteoric stones; and, indeed, while the learned were still questioning their existence, they had more than once given *striking* proofs of their destructive power. The companions of Cortez saw at Cholula a large meteoric stone which had fallen upon the temple. In 1654, a Franciscan monk was killed by a small aerolite near Milan; and Wallace, in his account of Orkney, mentions a fishing-boat which was struck by a meteoric stone near Copinshaw in 1676. On July 24, 1790, a stone fifteen inches in diameter fell into a hut near Bordeaux, where it killed a herdsman and a bullock. On May 19, 1853, at ten minutes past nine in the morning, an aerolite struck the wall of an iron suspension bridge at Mannheim, and was shivered into numerous pieces, the greater part of which unfortunately fell into the Neckar. Thus the Damocles' sword of a meteoric stone is constantly suspended over our heads; but, as it only strikes one person among many hundred millions, we need hardly fear coming to an untimely end in this singular manner.

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[1] Creg, 'Philosophical Magazine,' Nov.-Dec. 1854.

[2] Poggendorff's 'Annalen,' Band cv.

With regard to the chemical composition of meteoric stones, the actual number of recognised elements which they have been found to contain is nineteen or twenty—that is, about one-third of the whole number of elementary substances (or what we are yet forced to regard as such) discovered on the earth. All these aerolitic elements actually exist on the earth, though never similarly combined there. No new substance has hitherto come to us from without, and the most abundant of our terrestrial metals, iron, is that which is largely predominant in aerolites, forming frequently upwards of ninety parts in a hundred of the mass. Seven other metals—copper, tin, nickel, cobalt, chrome, manganese, and molybdene—enter variously into the composition of these stones. Cobalt and nickel are the most invariably present; but the proportion of all is trifling compared with that of iron. There have also been found in different aerolites six alkalis and earths—soda, potash, magnesia, lime, silica, and alumina—and, in addition to these, carbon, sulphur, phosphorus, and hydrogen. Finally, oxygen must also be named as a constituent of many aerolites, entering into the composition of several of the substances just mentioned.

A notable and very uniform character of recently-fallen aerolites is the shining dark crust enveloping them, which is found in no other stones or metallic masses belonging to our earth. It is generally very thin, but indicates by its aspect, and by its entire separation from the mass within; some rapid action of heat which has not had time to penetrate more deeply into the substance of the stone. Internally, they are greyish, and of a granulated texture, more or less fine.

Aerolites, though generally of a small size, have been found of vast weight and dimensions—such as the famous stone of Aigos Potamos. The one discovered at Otumpa, in Brazil, in a locality where there is no iron nor rock of any kind near the surface, weighs about 14,000 pounds; and another, discovered by Rubin di Colis, in the year 1783, at Tucuman, in La Plata, is estimated at 30,000 pounds weight. On the eastern bank of the Great Fish River, Captain Alexander found such enormous masses of metallic iron scattered over a wide surface of land as to raise doubts of their meteoric origin. But the chemical analysis of some fragments, subsequently made in England, fully proved their true nature. The three immense meteoric stones, discovered in 1870 by Nordenskjöld in Greenland, were transported in the following year to Copenhagen in a man-of-war specially sent out for the purpose. The largest of them, which is at the same time the largest known on earth, weighs 50,000 pounds, and now stands in the hall of the Academy of Science, where it is preserved under a hermetically-closed glass case. The two others weigh respectively 20,000 and 10,000 pounds, and together with smaller fragments must all have originally formed one vast meteoric mass, which either burst in the air or was shattered to pieces as it struck the earth.

After the learned had so long derided the notion of stones falling from the heavens as ridiculous, they now, when the fact was indisputably settled, exerted their ingenuity in endeavouring to account for the phenomenon. Some, giving a free scope to their imagination, supposed them to be formed, like snow or hail, by the condensation of ferruginous vapours and other substances dissolved or floating in the atmosphere; others, that they were the product of our own volcanoes—stones forcibly ejected thence, partaking for a time of the motion of the earth, but in the end returning to it. That no volcano has ever been known to cast forth masses of metallic iron, or stones of a composition at all approaching that of aerolites, was, it seems, entirely ignored by these bold theorists, as well as the circumstance that meteorolites are found many hundreds of miles from any active volcano—a distance to which no eruptive force could possibly hurl them.

A third hypothesis assigned to aerolites a lunar origin, supposing them to be projected from the huge volcanoes of our satellite (no atmospheric pressure existing to retard or arrest them) with force enough to exceed the limits of the moon's attraction, and to come within those of the earth. But though this notion was originally countenanced by such eminent men as Berzelius and Laplace, it encountered so many and such weighty objections that it has been finally abandoned as untenable.

The hypothesis which supposes not only meteoric stones and fire-balls, but the host of shooting stars in general, to come to us from the depths of celestial space, has far more probability in its favour. According to this view, which has derived argument and illustration from the whole course of modern physical research, and is chiefly founded on the periodical recurrence of showers of shooting stars at certain epochs of the year, on their extreme velocity, and on their motion, which is in general contrary to the direction in which the earth revolves, there exist in the planetary regions, independently of the great planets, myriads of small bodies which circulate round the sun, generally in zones. Some of these zones intersect the ecliptic, and are consequently attracted by the earth in its annual revolutions. Of the bodies thus attracted, by far the greater part are either entirely consumed as they shoot through the air with planetary velocity, and merely reveal their existence by the luminous track which precedes their extinction, or else are merely deflected in such degree towards the earth as to become luminous in a part of their course, yet still to preserve their own independent orbits, while a few only descend upon the earth in the form of fiery balls, and exploding before they fall give rise to the phenomenon of meteoric stones. We can easily imagine that the meteorites are not uniformly distributed throughout the whole circuit of the zones, but are congregated here and there in thicker groups; and this accounts for the periodical showers not always recurring with the same brilliancy.

According to Schiaparelli the phenomenon of shooting-stars is closely connected with the comets, and this opinion has been splendidly confirmed by the remarkable meteoric shower which took place on November 27, 1872, and was seen all over Europe and part of Africa. The greatest astronomers of the day, such as Klinkerfues, Secchi, Weiss, Galle, Forster, &c., all agreed that on that date the earth intersected the orbit of Biela's comet, which had been missed for some time, and that most probably the meteorites seen on earth as shooting stars followed in its train. Professor Klinkerfues, of Göttingen, assuming from the brilliancy of the shower that on November 27 our earth must have passed very near the head of the comet, calculated that, in case his assumption was right, the comet in question must be found near the star δ Centaur, provided the intelligence was forwarded in time to the southern hemisphere. He accordingly telegraphed on November 30 to the observatory at Madras to look for Biela's comet near δ Centaur, and was subsequently informed by a letter from Mr. Poyson, the director of that observatory, that he had actually found the comet in the place which had been mentioned in the telegraphic despatch, and had observed it several times on the 2nd and 3rd December. Thus, by a calculation founded on the point of radiation of a meteoric shower, a comet was detected in its course, and science celebrated a most interesting triumph. Still, however, the theory of shooting stars leaves many mysteries unexplained, and there is still a wide field open to the imagination in endeavouring to solve them.

So much is certain, that no mineral substances we know of afford a higher interest to the reflective mind than the aerolites. All other bodies we see around us belong originally to the substance of our earth, but here, and only here, the erratic boulders of another world are submitted to our view. We are able to touch bodies whose mysterious birthplace lies far beyond the utmost limits of our atmosphere; they come to us we know not whence; they were formed we know not how! They are the ponderable witnesses that the elements which compose the solid mass of our globe exist also beyond its limits; they afford us an insight into the material construction of the solar system, or even into that of the immeasurable universe.

The meteorites have also been of great importance in the history of civilisation, for there can hardly be a doubt that they first made man acquainted with the use of the metal which above all others has contributed to his progress. All iron of a terrestrial origin is combined with other substances which conceal its true nature from the uninitiated eye, and from which it is with difficulty separated; but here it lies at our feet like a pure gift from Heaven, and requires nothing but softening by fire and hammering to assume at once a useful form. As the Esquimaux of Baffin's Bay, long before Captain Ross discovered them in their icy solitudes, had found out the method to forge implements of the chase out of meteoric iron, thus also in pre-historic times this extra-terranean substance furnished man with his first iron spear or his first iron axe.

CHAPTER XXIII.

THE AURORA BOREALIS AND AUSTRALIS.

The Aurora Borealis—The Austral Light—The 'Merry Dancers'—Superstitious Notions—Ancient Accounts—Gassendi—Height of Auroras—Their Cause—Magnitude of the Phenomena.

NATURE has awarded its peculiar charms to every zone. Like a bounteous parent, she has forgotten no part of the earth in the distribution of her gifts, for even the dreary confines of the globe, where the cold of an eternal winter allows no plant to flourish, and but a small number of animals to live, have been superbly decorated by her lavish hand. There the icebergs swim upon the solitary seas like crystal rocks; there snowy peaks, romantic fiords, and vast glaciers, form scenes of a majesty unparalleled in other climes; and there, above all, the magic flames of the aurora illumine the long winter's night with a brilliancy unknown to the inhabitants of sunnier lands.

Darkness covers the face of the earth, the stars glimmer feebly through the haze which so frequently dims their lustre in the high latitudes, when suddenly a broad and clear bow of light spans the horizon in the direction where it is traversed by the magnetic meridian. This bow sometimes remains for several hours, heaving or waving to and fro, before it sends forth streams of light, ascending to the zenith. Sometimes these flashes of light proceed from the bow of light alone; at others they shoot forth simultaneously from many opposite points of the horizon and form a vast sea of fire, whose brilliant waves are continually changing their position. Finally, they all unite in a magnificent crown or cupola of light, with the appearance of which the phenomenon attains its highest degree of splendour. The brilliancy of the streams, which are commonly red at their base, green in the middle, and light yellow towards the zenith, increases, while at the same time they dart with greater vivacity through the skies, and form a spectacle which fancy may paint, but which language is unable to describe.

The colours are wonderfully transparent: the red of a clear bloody hue, the green of a pale emerald tint. On turning from the flaming firmament to the earth this also is seen to gleam with a magical light. The dark sea, black as jet, forms a striking contrast to the white snowy plain or the distant ice-mountain; all the outlines tremble as if they belonged to the unreal world of dreams. The imposing silence of the night heightens the charms of the magnificent spectacle.

But gradually the crown fades, the bow of light dissolves, the luminous streams become shorter, less frequent, and less vivid, and finally the gloom of night once more descends upon the desolate waste.

Such is generally the progress of a perfect aurora, which, however, is seldom seen in its full magnificence. Frequently the crown is missing; frequently also the play of colours is less vivid, and the streams of light of inferior length. The splendid phenomenon is commonly called the *aurora borealis*; but the polar aurora would be a more appropriate name, for it no less frequently flames over the frozen regions of the south than over those of the Arctic zone. In the southern hemisphere it, of course, became much later known, as the inclemency and vast distance of the Antarctic seas repelled for a long time the spirit of discovery. Captain Cook was the first who ventured among the icebergs of that desolate ocean, and to his companion Forster we owe the first accurate description of an austral aurora.

'A beautiful phenomenon,' says the eminent naturalist, 'was observed during the preceding night (February 17, 1773, 58° S. lat.), which appeared again this and several following nights. It consisted of long columns of a clear white light, shooting up from the horizon to the eastward, almost to the zenith, and gradually spreading on the whole southern part of the sky. These columns were sometimes bent sideways at their upper extremities, and though in most respects similar to the northern lights of our hemisphere, yet differed from them in being always of a whitish colour, whereas ours assume various tints, especially those of a fiery and purple hue. The sky was generally clear when they appeared, and the air sharp and cold, the thermometer standing at the freezing-point.'

The austral light must, however, have been observed long before Cook and Forster, as it is frequently seen on the Chiloe Islands, and cannot fail to have attracted the attention of vessels sailing round Cape Horn. Its light is sometimes so brilliant as to enable the spectator to read large print, or to cast his shadow on the deck.

In high latitudes the aurora is a very common phenomenon, so that during his eight months' residence at Bossekop (70° N. lat.), on the coast of West Finnmark, the French naturalist Lottin observed no less than 143 northern lights, of which 64 occurred during the longest night, which then lasts from November 17 till January 25. The chief seat of the aurora borealis seems, however, to be the region between 60° and 66° N. lat. At Rensselaer Harbour (78·5° N. lat.) and Port Foulke (78·20° N. lat.) it was but rarely seen by Kane and Dr. Hayes, and the latter was told by his interpreter Jensen that at Upernavik (72° N. lat.) the phenomenon was much more brilliant, and of greater frequency.

In the northern wilds of Sweden and Lapland it is not only an object of pleasing curiosity, from the singular beauty of its appearance, but is extremely useful to travellers, by its almost constant emission of a very brilliant light. In Hudson's Bay it is said to possess a variegated splendour equalling that of the full moon. 'In the north-eastern parts of Siberia,' says Gmelin, 'these northern lights are observed to begin with single bright pillars rising in the north, and almost at the same time in the north-east, which, gradually increasing, comprehend a large space of the heavens, rush about from place to place with incredible velocity, and finally almost cover the whole sky up to the zenith, and produce an appearance as if a vast tent was spread in the heavens, glittering with gold, rubies, and sapphires. A more beautiful spectacle cannot be painted; but whoever should see such a northern light for the first time could not behold it without terror. For however fine the illumination may be, it is attended, as I have learned, with such a hissing, cracking, and rushing noise through the air as if the largest fireworks were playing off. To describe what they thus hear, the Siberians say that "the raging host is passing." The hunters who pursue the white and blue foxes in the confines of the icy sea, are often overtaken with these northern lights. Their dogs are then so frightened that they will not move, but lie obstinately on the ground till the noise has passed. Commonly calm and clear weather follows this kind of northern light. I have heard this account not from one person only, but confirmed by the testimony of many who have spent part of several years in these very northern regions, and inhabited different countries from the Jenissei to the Lena, so that no doubt of its truth can remain.'[1]

This account of the noise attending the aurora in the northern regions, allowing for some degree of exaggeration, has been confirmed by other observers, who compare it to the rustling of a piece of silk when it is rolled up, or to the hissing of the flames of a conflagration when agitated by the wind. Admiral Wrangell, however, never heard anything like a noise attending the phenomenon, and M. de Saussure, who observed it in the island of Skye, was not more fortunate, though the Shetlanders unanimously told him that a noise, like that caused by a van, constantly accompanies a strong aurora. Possibly the sounds said to proceed from the phenomenon may be a mere illusion of the fancy. 'The scene was noiseless,' says Dr. Hayes,[2] 'yet the senses were deceived, for unearthly sounds seemed to follow the rapid flashes, and to fall upon the ear like the tread of phantoms.' So much is certain, that no noise attended the appearance of the northern lights that flashed over central Europe in 1839 and 1872.

In Greenland and Iceland the aurora appears on every serene night. In the Shetland Isles the *merry dancers*, as they are there called, are the constant attendants of clear evenings, and afford great relief amid the gloom of the long winter nights. Farther to the south the phenomenon becomes more and more rare, and but seldom shows itself in France and Germany.

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[1] 'Philosophical Transactions,' vol. lxxiv. p. 228.

[2] 'The Open Polar Sea,' p. 217.

On October 18, 1836, central Europe, after a lapse of six years, enjoyed the sight of a superb aurora. It then appeared with a splendour which would have been deemed uncommon even in the higher latitudes, and made the famous astronomer Bessel confess that he felt himself quite incompetent to describe its constantly changing magnificence. The most southern point where it was observed was Turin; while the aurora of October 22, 1839, reached as far to the south as Rome, and that of October 19, 1726, was even seen in Portugal (37° N. lat.). But no northern light has ever been known to shoot forth its streams so vividly towards the Equator as that which illumined all Europe on February 4, 1872, and was even admired at Alexandria (31·5° N. lat.). The enlightened Parisians expressed their belief that it foretokened dreadful wars, and that the cherished days of 'revanche' were rapidly approaching; nor can we wonder that a phenomenon so awfully grand and surprising should have terrified the ignorant and superstitious of all ages. In the northern islands, the rustic sages who observe the blood-red flames of the aurora shooting through the skies become prophetic, and terrify the spectators with awful menaces of war, pestilence, and famine. Their excited fancy sees hosts of spirits flitting along upon its flashing beams, and holding their revels in the skies.

> The monk gaz'd long on the lovely moon,
>   Then into the night he looked forth;
> And red and bright the streamers light
>   Were dancing in the glowing north.
> So had he seen, in fair Castile,
>   The youth in glittering squadrons start;
> Sudden the flying jennet wheel,
>   And hurl the unexpected dart.
> He knew, by the streams that shot so bright,
> That spirits were riding the Northern Light.
>
> '*Lay of the Last Minstrel.*'

In the splendid imagery of Scandinavian mythology the aurora was the beard of the war god Thor, who in the 'Saga of King Olaf'[1] describes it among his attributes, along with the lightning flashing from his eyes, and the thunder of his rolling chariot wheels.

> The light thou beholdest
> Stream through the heavens
> In flashes of crimson,
> Is but my red beard
> Blown by the night wind,
> Affrighting the nations.

Though the aurora is but seldom distinctly seen in more southern latitudes, we find in Aristotle descriptions of fiery meteors, which can hardly be ascribed to any other phenomenon. The great philosopher speaks of blood-red columns or flames wavering in the air; and Pliny and Seneca likewise mention the appearance of a burning sky. Similar accounts, evidently pointing to the aurora, are met with in the chronicles of the middle ages, which in the superstitious spirit of those dark times attach all sorts of fearful prognostics to its appearance, but for its first accurate description we are indebted to the celebrated Gassendi. This remarkable man (born 1592, died 1658), who, in the sixteenth year of his life, occupied the chair of a professor of rhetoric at Digne in Provence, took, when a child, particular delight in gazing at the moon and stars as often as they appeared in clear unclouded weather. This pleasure frequently drew him into solitary places, in order to feast his eye freely and undisturbed, so that his parents had often to make long and anxious searches before they could find the precocious child, who forgot everything else while contemplating the skies. The magnificent northern light of September 12, 1621, could not escape the attention of so enthusiastic an observer. He also first gave it the fine poetical name of the aurora borealis, which its beauty, rivalling that of the early dawn, so well deserves.

The light emitted by this wonderful phenomenon is extremely various in intensity, though it is generally so feeble that even small stars are visible through its streamers. Sir David Brewster estimates it to be equal to that of the moon in its first quarter when the sun is several degrees below the horizon; and according to Scoresby, who frequently observed it in high latitudes, the light of an aurora reaching to the zenith is about as great as that of the full moon. De la Pelaye, however, mentions having seen northern lights in Newfoundland, the brilliancy of which penetrated even the thick fogs so common in that country, and cast a shadow upon the ground; and Löwenorn assures us that in Greenland he saw even by daylight the streaming pulsations of a polar light, a phenomenon which was also distinctly observed at Amsterdam on December 4, 1845, between two and three o'clock in the afternoon.

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[1] Longfellow, 'Tales of a Wayside Inn.'

The circumstance that auroras of considerable brilliancy are seen over a great part of the earth, naturally led philosophers to enquire after their height. Father Boscovich determined that of one observed on December 16, 1737, by the Marquis of Poleni, to have been 825 miles high; and the celebrated chemist Bergman, from a mean of thirty computations, makes the average height of the aurora to be 70 Swedish, or upwards of 460 English, miles, which is far above the calculated limits of our atmosphere. Euler even supposes it to be several thousand miles high; and Mairan also assigns to the 'merry dancers' a very elevated region for their aerial gambols.

On the other hand, the observations of modern travellers, particularly of our arctic explorers, have greatly reduced the supposed height of the aurora.

Scoresby mentions one in 65° N. lat., which descended so low that its flashes seemed to touch the points of the masts. Franklin, Hood, and Richardson assure us that though the aurora varies in height at different times, and they never made any direct measurements of its altitude, they often saw it flashing between the earth and the clouds. Richardson even mentions an instance of his seeing a bright aurora, which remained unperceived by one of his companions who was keeping watch at the time not twenty miles distant, and consequently observing the horizon with an attentive eye. Farquharson saw, several times, the streamers of the northern light projected upon the clouds, which were evidently higher than the phenomenon itself. It is now generally supposed that the height of the aurora does not exceed twenty miles.

With regard to its cause, philosophers of great eminence have given their authority to the most extravagant theories. Their imaginations have kindled bonfires in the poles of the earth, and they have represented the northern lights as the effects of flames, to which those lights have scarcely any similarity, and from which they are distinguished by numberless diversities. The vast salt pits of the north, which existed nowhere but in the fancy of those who talked of them, were also at one time regarded as emitting a luminous effluvium, copious enough to pervade the whole of our northern atmosphere. At a later period the aurora was supposed to be an electrical phenomenon, and then again a stream of magnetic light emanating from the poles of the earth, which was considered as a great magnet. This theory has also been found untenable. There can, however, be no doubt that the aurora bears some relation to terrestrial magnetism, for not only is it constantly observed in the direction of the magnetic meridian, but its appearance is also generally attended with great oscillations of the magnetic needle. Terrestrial magnetism likewise attains its maximum a short time before the appearance of an aurora, and diminishes again as the vivacity of the latter increases. 'The magnificent phenomenon of the coloured polar light,' says Humboldt, 'indicates the discharge and termination of a magnetic storm, as in an electrical storm, the restoration of the disturbed electrical equilibrium of the atmosphere is shown by the emission of lightning.'

According to recent observations the aurora seems to be intimately connected, and to follow a parallel course with the formation of the solar spots, as it appears most frequently when the latter are largest, and conversely.

It has also been found by the comparing of observations that the polar light appears simultaneously in both hemispheres, so that it is not only one of the most beautiful, but probably also the grandest, of all the atmospherical phenomena. The thunderstorm vents its rage over a narrow space, and at the distance of a few miles the elements are at rest;

even the cyclone whirls in its destructive path over a comparatively small part of the earth's surface, but the aurora flashes from both poles at once, and darts at the same time its flaming streamers both over the northern deserts where the Schaman beats his magical drum, and over the desolate wilds where the Fuegian culls shell-fish from the rock. It casts simultaneously its lurid glare over the Straits of Behring and those of Magellan; it is the splendid crisis of a mysterious disturbance which affects the magnetic power all over the earth, and has for its scene the opposite ends of the globe.

CHAPTER XXIV.

THE PRIMEVAL ATMOSPHERE.

The Atmosphere in the Silurian Times—Trilobites—The Chemical Composition of the Primeval Atmosphere—Enormous Change of Temperature in Course of Time—Mildness of Climate in the Arctic Regions during the Miocene Period —The Glacial Period.

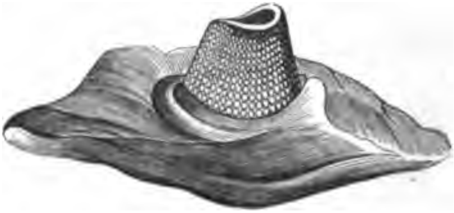
WHEN we consider the perpetual changes which have taken place since the primeval times in the forms of animals and plants, we are naturally led to the enquiry whether similar changes have not occurred in the condition of the atmosphere; whether the air we breathe is of the same composition as that which waved round the forests of the carboniferous period, or which was inhaled by the ichthyosaurus or the mylodon.

A direct and positive answer to this interesting question cannot indeed be given, for whatever changes may have occurred in the aerial regions during the lapse of uncounted centuries, they have not been able to leave us the petrified memorials of their progressive history. But the dependence of all animal and vegetable life upon the atmosphere permits us at least to draw some conclusions from the fossil remains of extinct races to the state of the air they breathed, and to transport ourselves, as it were, on spiritual wings into the aerial ocean of the primeval times.

Wandering far, far back to the shores of the Silurian Seas, we find them peopled with the singular race of the trilobites. But few petrifactions are more entitled to our wonder, both from their number and the multiplicity of their forms, than these strange crustaceans, which, by their three-lobed harness, deviate so much from all their living relatives.

With regard to the question which now occupies our attention, we are, however, chiefly interested with their large eyes, composed, like those of the dragon flies, of many hundreds of spherical facets whose structure plainly shows that the waters of the primeval ocean were as limpid as those of the present seas, and that the relations of light to the eye and of the eye to light, and consequently also the transparency of the atmosphere ,cannot have undergone any material change since those times.

TRILOBITE.



EYE OF TRILOBITE HIGHLY MAGNIFIED.

Thus, before the oldest coal-beds were formed, the moonbeam was reflected as brightly as it is now from the crest of the curling waves; when the sun set, he cast the same golden rays over the undulating ocean and produced in the Silurian forest the same picturesque effects of light and shade which enchant the lover of Nature in the woods of the present day.

With regard to the chemical composition of the primeval atmosphere the enormous deposits of carbon in the coal-fields seem to warrant the belief that the air at that period contained more carbonic acid than at present. Those enormous and luxuriant forests whose accumulated remains furnish a great part of the human race with fuel, and will probably for hundreds and thousands of years to come set the steam-engines of future races in motion, gradually condensed into a solid form the carbon which had previously been floating in the atmosphere in a gaseous condition, and reduced its quantity to the present proportion. Even now, carbonic acid is evolved from thousands of volcanic vents, and would gradually accumulate in the air to the detriment of animal life, if the ever active world of plants were not continually decomposing it into carbon and oxygen, and maintaining the existing equilibrium of the atmosphere. In the comparative youth of our planet, when its heat was greater and its solid crust less thick than now, volcanic fumes must have been exhaled in far greater quantities.

There is, however, reason to doubt whether, even long previously to the coal period, the quantity of carbonic acid mingling with the atmosphere was ever such as to render the life of birds or quadrupeds impossible, for we are told by Liebig that if the carbon of all the plants and coal strata known to exist on earth were to be volatilised, it would hardly double the quantity of the carbonic acid actually floating in the air, and consequently not render it unfit for the respiration of the higher orders of animals.

While the composition of the primeval atmosphere is mere matter of conjecture, it is a well-ascertained fact that its temperature has undergone enormous changes in the course of time. The air of the carboniferous period may possibly not have contained quite so much carbonic acid as our vast coal-fields incline us to believe; but no one can doubt that at the time when they were formed, the atmosphere of the northern regions of the globe was much warmer than at present, as coal has been discovered even in Spitzbergen and Bear Island, and the forests which produced it must have required at least a temperate climate for their growth. Even in periods of a comparatively modern date, when the plants and animals already greatly resembled those of the present day, when man himself may possibly have already existed on earth, we have the most evident proofs of the enormous changes which have taken place in the temperature of the atmosphere.

At Anakerdluk, in North Greenland, in 70° N. lat., a large forest lies buried on a mountain surrounded by glaciers 1,080 feet above the level of the sea. Not only the trunks and branches, but even the leaves, fruit-cones, and seeds, have been preserved in the soil, and enable the botanist to determine the species of the plants to which they belong. They show that besides firs and sequoias, oaks, plantains, magnolias, elms, and even laurels, indicating a climate such as that of Lausanne or Geneva, flourished during the Miocene period in a country where now an almost perpetual winter compels even the hardy willow to creep along the ground. During the same epoch of the earth's history Spitzbergen was likewise covered with stately forests, and poplars and plantains grew where now the fugitive summer scarcely gives birth to a few stunted herbs in particularly favoured situations.

At the same period central Europe enjoyed a climate such as is now met with only in sub-tropical countries. At Oensager, in Switzerland, Professor Oswald Heer has discovered in the newest strata of the Upper Miocene more than 500 species of plants having the most striking resemblance with the flora of South Carolina. Tortoises and salamanders of a gigantic growth then crept over the soil of Helvetia. A long-armed ape of human stature then also lived at the foot of the Pyrenees, and other large monkeys roamed about the forests at Eppelsheim, near Darmstadt, as well as on the classical ground of Athens.

Many other instances might be brought forward of the general mildness of climate which then reigned in Europe, and gave birth to luxuriant forests far beyond the Arctic Circle. How different is the picture shown us by the far more recent Glacial Epoch, when enormous glaciers, descending from the Alps to the Jura mountains, filled the whole intermediate valley, and on the south side of that mighty chain descended towards the plains of the Po, where they have left vast moraines as a testimonial of their past existence, and have written the history of the atmosphere in characters of stone.

In the midst of the Glacial Period we find traces of a time when the temperature of the air again rose, and the climate of Switzerland resembled that of the present day. For the lignite bed of Dürnten, which beyond all doubt was formed during that intermediate period, since it reposes on the striated bed of an ancient glacier, and carries large erratic blocks on its surface, contains pine-cones and aspen leaves, insects and snails of existing species. After this genial interval the cold once more prevailed, and the glaciers which had retreated again advanced, if not on the former gigantic scale, at least in far more colossal dimensions than the greatest Alpine glaciers of our day.

In England, the lignite or forest bed of Cromer,[1] on the Norfolk coast, presents a singular analogy to that of Dürnten. It contains in a like manner the cones of the spruce and the Scotch fir, and shells and mammalia in common with the Swiss deposit, and was also preceded and followed by a period of greater cold. The antecedence of a colder climate is proved by the arctic character and more ancient date of a large proportion of the shells of living species included in the adjacent marine strata; and, on the other hand, proofs that it was followed by an era of severe cold are shown by the fact of its underlying a great mass of glacial drift.

What may have been the cause of these astounding atmospherical changes, which no doubt have been repeated more than once during the long history of our planet?

Did they result from geographical changes, or from variations in the relative position of our planet to the other heavenly bodies?

So much is certain, that the geologist finds the undoubted records of their existence in monuments of stone and fossil memorials, and that in the course of times whose length escapes the feeble grasp of our imagination, they have more than once changed forest lands into icy wildernesses, and glacial wastes into countries covered with a luxuriant vegetation.

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[1] Lyell's 'Principles of Geology.'

CHAPTER XXV.

WEATHER PROGNOSTICS.

The Dependence of Man on the Atmosphere—Narrow Scope of Trustworthy Weather Prognostics—The Moon—The Barometer—Weather Signs from the Heavenly Bodies—From the State of the Atmosphere—From Animals—Quatremére de Quincy—Spiders—Who are the Best Weather Prophets?

PRESUMPTUOUS man calls himself the Lord of Creation, and yet he is so absolutely dependent upon all the whims and caprices of the weather, that he might far more justly be called the slave of the atmosphere. His temper, his health, his fortunes, are all alike subject to this despotic power. The farmer anxiously consults his barometer in hopes of a rise of the mercurial column, for a long-continued rain drenches his fields, and threatens to deprive him of the fruits of his labour; and then, again, when a prolonged drought parches the drooping corn, he sighs for dark clouds and refreshing showers. The sailor steers towards the harbour with swelling sails, anticipating in thought the pleasures that await him on shore, but suddenly the wind changes, and drives him far out into the turbulent ocean; while others, long kept in port by contrary gales, quit the harbour he vainly hoped to reach, and exult in the favourable breeze.

Indeed, every change in the condition of the atmosphere brings joy to some, sorrow to others, and, on turning from the contemplation of private life to the great scene of history, we find that the destiny of nations has not seldom depended on some unexpected vicissitude of the weather.

Considering this vast influence which the atmospherical changes exert on the march of human affairs, we cannot wonder that since the remotest antiquity man has been constantly endeavouring to discover certain rules for prognosticating the weather.

The wild contemporaries of the cavern bear, when about to chase the mammoth or the reindeer, no doubt interrogated the aspects of the sky as wistfully as the people of our days when preparing for a picnic or a journey; and weather prophets have abounded, and found belief in every age and in every zone, among savages as well as among civilised men.

The South Sea Islander has his wind conjurors, the negro his rain doctors, and we our weather almanacks, which foretell for months to come

> By *sure* prognostics when to dread a shower;

but which, like Murphy's Almanack, which was found by Dr. Lardner to fail in seventeen cases out of twenty-four, are *sometimes* mistaken.

The greatest ignorance always shows the firmest belief in far-reaching weather prophesies; and it is only when we have gained some insight into the grand laws which regulate the atmospherical changes, that we begin to see the very narrow range of trustworthy weather prognostics.

But although every one who has any idea of the many conflicting influences which determine the weather of our changeful climate, knows that the strife, whether a rainy west wind or a dry eastern breeze, is to predominate within the next few days, is often determined hundreds of miles from our shores, and is convinced by this circumstance alone of the utter impossibility of truly predicting the weather for months or weeks, still there are some signs which afford the practised eye tolerably safe indications for foretelling such changes of the weather as we may expect for some days or hours, or which even allow us to conjecture the probable character of the next season.

The old saying, for instance, that the greatest cold is about to set in when the days lengthen, is verified by experience, in spite of many exceptions, as the coldest days of winter fall on an average between the 6th and the 15th of January, when the days are already perceptibly lengthening.

The saying, 'A peck of March dust is worth a king's ransom,' is so far right that in a hundred years a warm April has been found to follow seventy-nine times after a dry March; but still, a warm April not seldom succeeds a wet March, as well as a cold and rainy April a dry March.

The days have long since gone by when Jupiter or Saturn were supposed to influence our destinies, but the faith of mankind in general in the influence of the moon on the weather has never been shaken, and even now, when knowledge is so widely diffused, and physical science brought, as it were, to the doors of all who have the slightest pretention to education, this belief is almost universal.

If the moon act upon our atmosphere by attraction, as she acts upon the waters of the ocean, she will produce atmospheric tides. The greater mobility of air will cause those tides to be formed more rapidly than the water tides; and it may perhaps be assumed that they will always be placed either exactly or very nearly under the moon. Thus, as there is high water twice daily, so would there be high air twice daily, and the times of this air tide would correspond with the moments of the transit of the moon over the meridian above and below the horizon. The same causes also which at new and full moon produce spring tides, and at the quarters neap tides, would produce spring and neap atmospheric tides at the same epochs. At new and full moon, therefore, the air ought to be higher daily at noon and midnight than at any other times during the month; and, on the other hand, at quarters it ought to be lower.

But we have seen in another chapter that the diurnal fluctuations of the barometer can by no means be attributed to lunar attraction, the effects of which at the epochs of the high and low atmospheric tides have been found, from thousands of observations rigorously investigated by Arago, Laplace, and others, to be within $\frac{1}{600}$ of an inch—a quantity such as could produce no conceivable effect upon the weather.

Thus it is evident that if the moon have any influence on our atmosphere, it cannot proceed from any cause analogous to that which produces the tides of the ocean.

The opinion that the epochs which mark the principal phases of the moon are in the majority of cases attended with a change of the weather is likewise unsupported by fact. In the years 1774 and 1775 Dr. Horsley directed his attention to the question, and published two papers in the 'Philosophical Transactions,' with a view to dispel the popular prejudice on the subject of lunar influences. He found that in the year 1774 there were only two changes of weather which corresponded with the new moon, and none with the full moon, and that in the year 1775 there were only four changes which corresponded with the new moon, and three with the full moon.

It is generally supposed that the full moon has the property of dissolving thin clouds into invisible aqueous vapour, and this dissolving power has been attributed to the calorific rays of the moonlight, which are indeed mostly absorbed in the highest regions of the atmosphere. But here again accurate observations by no means ratify the popular belief. According to Mr. Loomis's calculations of observations made during seven years at Greenwich, it would even seem that cloudy weather is more common at the time of full moon than at new moon.

Supposing the visible firmament to be divided into ten equal parts, then, on an average—

At new moon	6·60
„ first quarter . . .	6·64
„ full moon	6·68
„ last quarter . . .	6·76

of these parts are covered with clouds at Greenwich.

Dr. Ellner, in Bamberg, who has made similar observations during many years, has found about the same result, his maximum of cloudy weather coinciding with the full moon, and his minimum with the first quarter.

In fact, neither theory nor experience leads to the conclusion that the effects which the attraction, or the light, or any other physical influence of the moon, may be supposed to produce upon the weather, are in accordance with observed phenomena. These effects are either too small in amount to be appreciable in the actual state of meteorological knowledge, or they are obliterated by other more powerful causes; and thus all weather prognostics so confidently derived from the influence of the moon are neither more nor less than popular fallacies.

The use of the barometer as an indicator of the state of the weather is founded on the observation that in our climate it is generally above 30 inches in fine weather, and below this point when there is rain, snow, wind, or storm; and also that for any given number of days at which the barometer stands at 30 inches there are as many fine as rainy days. From this coincidence between its height and the state of the weather the following indications have been marked on the barometer, counting by thirds of an inch above and below 30 inches:—

Height	State of the Weather
31	Very dry
30⅔	Settled weather
30⅓	Fine weather
30	Variable
29⅔	Rain or wind
29⅓	Much rain
29	Tempest

But though a change in the weather frequently coincides with the change in the pressure of the atmosphere as indicated by the barometer, they are not necessarily connected. This coincidence results from meteorological conditions peculiar to our climate, and does not always occur. That a fall in the barometer usually precedes rain in our latitudes is caused by the position of Europe as the condenser of the Atlantic. The south-west winds, which are hot, and consequently light, make the barometer sink; but, at the same time, as they become charged with aqueous vapour in crossing the ocean, they bring us rain. The north and north-east winds, on the contrary, being colder and denser, make the barometer rise; and, as they only reach us after having passed over vast continents, they are generally dry.

When the barometer rises or sinks slowly—that is, for two or three days towards fine weather or towards rain—it has been found from a great number of observations that the indications are then extremely probable. Sudden variations in either direction indicate bad weather or wind.

The various aspects of the sun, moon, and stars, and the clear or troubled state of the atmosphere, afford us many more or less probable indications of a coming change in the weather.

Rain may be expected when the sun rises pale, and when after his setting clouds ascend in the part of the sky whence the wind blows.

A red morning sky is as frequently followed by rain as the sun setting in red clouds by fair weather.

According to Schübler, the probability in the first case is as 61·6 to 6·8, in the second as 63·7 to 16; so that we have some reason to trust the old adage,

> Evening red and morning grey
> Will help the traveller on his way;
> But evening grey and morning red
> Will bring down rain upon his head.

A moon pale in colour, with horns blunt at first rising; the stars seeming large, dull, and pale of colour, or when their twinkling is not perceptible, or if encompassed with an iris, are signs of rain.

If mists be attracted to the tops of hills, then expect rain in a day or two; if in dry weather they be observed to ascend more than usual, then expect sudden rain; but if mists dissipate quickly, or descend after rain, it is a sure sign of fair weather. If after sunset or before sunrise a white mist arise from the waters and meads, it denotes fair and warm weather next day.

If the rain begins an hour or two before sunrise, it is like to be fair ere noon; but if an hour or two after sunrise, it continues for the most part all day.

A bright moon with sharp horns; the wind shifting to the east or north; a sky full of twinkling stars; small clouds hovering low in the north; snow falling small, while clouds appear on heaps like rocks—are signs of cold and frosty weather.

Snow falling in large flakes, while the wind is in the south; cracks appearing in the ice; sun looking waterish;

the moon's horns blunted; stars looking dull, wind turning to the south; wind extremely shifting—are signs of thaw.

The weather prognostics derived from the animal creation are often more to be relied upon than any others. The lassitude and undefinable anxiety which nervous individuals feel before a thunderstorm, the shooting pains of old wounds and scars, the aching and pricking of chilblains and corns, the attacks of headache and of the gout when a considerable change in the weather is about to take place, entitle many sensitive persons to be called living barometers.

A great number of animals indicate by their deportment a change in the weather. Before rain, and when a storm is approaching, they are seized by an unusual uneasiness or activity; the sea and water fowls are seen flying to land, and many land birds to water, the frogs croak from the ditches, the worms crawl out of the earth in great abundance, the loach stirs about in the sand, the sheep leap or push one another in an unusual manner, the cock crows, and the peacock screams late and early, the gnats sting, and the ants are seen busily running to and fro.

'The Arctic diver[1] enjoys among the Norwegians the reputation of a most excellent weather prophet. When the skies are big with rain, the birds fly wildly about, and make the most horrible hoarse noise, fearing that the swelled waters should invade their nest; on the contrary, in fine weather their note is different, and seemingly in an exulting strain. For this reason the Norwegians, who, being mostly a maritime population, pay the greatest attention to the aspect of the sky, think it impious to destroy, or even to disturb this species.'

It is universally known that the swallows fly low at the approach of rain, as the insects whom they pursue retire from the higher and more humid aerial strata to a lower level, where the atmosphere is still dry and warm. Then also the fishes spring frequently out of the water to catch the insects that are flying near its surface. When rain is impending, the snails are said to crawl upwards on stones and trees, while the crickets and grasshoppers seek shelter under leaves and in hollow trees.

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[1] 'The Sea and its Living Wonders,' 4th edition, p. 150.

Fine weather may be expected when the halcyons and sea-ducks leave the land and flock to the sea, when the larks soar high and are loud in their notes, when the bees roam about at a great distance from their hives, and the bats appear early in the evening.

The tree-frog has proved unworthy of his reputation as a trustworthy weather prophet, while the spiders seem to be more deserving of the credit they first obtained through the French General Adjutant Quatremère-Disjonval. This officer, having been made prisoner by the Dutch during the war of 1794, was a careful observer of the habits of the house spider, during his confinement at Utrecht, a circumstance which was destined to play an important part in the history of Holland; for General Pichegru, being prevented by the mild weather from carrying out his intention of invading that country, was about to retire with his army from the Dutch frontiers, when Quatremère found means to inform him that, from the signs he had observed in his spiders, a severe frost was sure to take place within the next ten days. Pichegru trusted to the prognostic—the frost came in time, Holland was conquered, and Disjonval released from his prison.

Voigt[1] finds the physiological reason for the accurate weather indications afforded by spiders in their large abdomen and their slender elongated limbs, the former being influenced by the dryness or moisture of the air, while the latter are particularly sensitive to warmth and cold. This explains how the spider sometimes stretches out her legs, and at others draws them in, or how she sometimes weaves her net in order to get rid of superfluous humours and sometimes not. Her sensations of hunger and thirst, her activity and rest, will likewise conform to the state of the atmosphere, and be influenced by the approaching changes of the weather.

According to Voigt's observations, fine weather may confidently be expected when the garden spiders appear in greater number, and weave large webs, or when they make a new web during the night, and also when the house spider shows her head in her web and stretches out her feet.

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[1] 'Lehrbuch der Zoologie,' vol. iv. p. 125.

Variable weather is indicated when there are but few garden spiders, which work faintly and only weave small webs; while rain is at hand when the garden spiders do not weave at all, and the house spiders hide their heads in their webs, and show their hinder extremities. Thunderstorms and wind are indicated when the garden spider tears her best web, and conceals herself in a corner at its summit. A severe winter cold is announced by the house spiders leaving their corners in a hurry, and fighting for the possession of the best situated webs, or weaving new webs, or weaving in the night several webs the one over the other. Voigt recommends that the largest and oldest spiders should be selected as weather prophets, and that they should be observed frequently, but without coming too near them, so as not to disturb them in their operations.

The early arrival of the migratory birds is generally considered as the sign of an early spring; and not without reason, as the birds follow the warm upper air-stream which may be expected soon to descend to the surface of the earth, and to warm the soil and the air. The early appearance of the birds in the autumn is likewise a sign that the winter has already begun in the northern regions and will probably soon visit our country.

As the circumstances which influence the weather are extremely numerous and intricate, the art of prognosticating its course with some certainty cannot be theoretically learnt, but only obtained by long-continued practice and diligent observation. The shepherd who passes his solitary hours in constant communion with Nature, and knows how to read in the clouds; the sailor, whose eye roams for weeks over a boundless horizon, and follows with attention every change in the sky; or the fisherman, to whom every change in the state of the atmosphere is of importance, will always be better weather prophets than the learned theorist, who trusts more to books than to personal observation, and spends the best part of his life, not in the free open air, but in the seclusion of his study.

CHAPTER XXVI.

THE ATMOSPHERE AND THE SOLID EARTHRIND.

Levelling Power of the Atmosphere on the Solid Earthrind—Expansive Influence of Frost on Water a Cause of Disintegration of Rocks--Mountain Torrents—The Undermining Power of Rain—Landslips—Disintegration of Stones Caused by Excessive Warmth—The Sea an Auxiliary of the Air in the Work of Destruction—Carbonic Acid another Auxiliary—The Atmosphere a Destroyer and Beautifier—Influence of the Configuration of the Earth on Atmospherical Phenomena—Influence of Earthquakes on the Weather—Connexion between the Atmospheric and Subterranean Regions.

HOW immovably firm is to all appearances the earth, with its ribs of granite and sandstone, of trap and lava, of limestone and basalt! How proudly the mountain raises its snow-capped summit to the skies, as if bidding defiance to eternity! How inconstant, how fluctuating, how changeable, seems, on the other hand, the air, which the puniest insect traverses in every direction, and which so readily obeys every external impulse. On a superficial view it might as well be called the symbol of instability as the solid earth—the symbol of firmly-rooted strength.

And yet this apparently so feeble element is endowed with powers which in the course of time irresistibly destroy the hardest rock, and level the proudest mountain with the dust. No less than three-fourths of the surface of all the continents and islands consist of strata which, superposed one above the other in successive layers, contain the fossil remains of a long series of extinct animals and plants, and all these strata, often many thousand feet thick, are the trophies of aerial power. They once rose as mighty mountain chains and lofty lands, high over the primeval ocean, but the action of the atmosphere gradually broke and pulverised them, and swept them from a higher to a lower level, and finally transformed them into the gigantic cemeteries of extinct creations.

A considerable part of the human race is settled on the fruitful soil of the river deltas, or the low plains through which the Ganges, the Nile, the Danube, the Rhine, and a hundred other streams, slowly wend their way to the ocean, and all these deltas and plains owe their existence to the atmosphere. Millions and millions of years may have passed away since it first began the work of destruction, and throughout all this incalculable time the air has but little varied in the proportions of its constituent parts, while the surface of the solid earth has undergone perpetual transformations; and thus we well may ask which is strongest—the apparently solid and immovable rock, or the light and gaseous atmosphere above it.

The weapons with which the air wages this unequal war are its ever-changing temperature, and the levelling power of the waters which it precipitates from its bosom.

Wherever the naked rock is exposed to the severity of winter, the frost expands the moisture which, during summer or during the warm hours of the day, had penetrated into the pores or crevices of the stone, and detaches one boulder after another from the bald summit of the mountains. 'Under the wintry sky of St. Lawrence Bay (Behring's Sea),' says Chamisso, who in this desolate country was particularly struck with the effects of atmospherical action, 'the mountains unprotected by vegetation grow old and fall into decay. Each winter's frost rends the rocks asunder, each summer's rain detaches new ruins, and destruction proceeds till it has completed its work. Under a more fortunate sky the poet points out to us in the forest-crowned hill the image of eternal stability, but the gloomy song of the northern bard shows us in the crumbling rock the destructive power of age.'

Even under the vertical rays of the tropical sun, the snowy peaks of the Cordilleras or of the Himalaya exhibit the same pictures of wintry desolation which struck Chamisso in the arctic wildernesses of Behring's Sea; and wherever the Alps, or the Pyrenees, or the mighty Caucasus, tower above the snowline, we find the climate of Spitzbergen or Iceland. Thus in all zones frost exercises its destructive power; in all zones its constant tendency is to reduce all that is elevated to a lower level. The stones it detaches from the parent rock are then carried away by the transporting power of the glacier, or the violence of the rushing stream.

'The rivers,' says Mr. Darwin,[1] 'which flow in the valleys of the Cordilleras, ought rather to be called mountain torrents. Their inclination is very great, and their water the colour of mud. The roar which the Maypu made as it rushed over the great rounded fragments, was like that of the sea. Amidst the din of rushing waters, the noise from the stones, as they rattled one over another, was most distinctly audible even from a distance. This rattling noise, night and day, may be heard along the whole course of the torrent. The sound spoke eloquently to the geologist; the thousands and thousands of stones, which, striking against each other, made the one dull uniform sound, were all hurrying in one direction. It was like thinking on time, where the minute that now glides past is irrecoverable. So was it with these stones—the ocean is their eternity, and each note of that wild music told of one more step towards their destiny.

'It is not possible for the mind to comprehend, except by a slow process, any effect which is produced by a cause repeated so often, that the multiplier itself conveys an idea not more definite than the savage implies when he points to the hairs of his head. As often as I have seen beds of mud, sand, and shingle, accumulated to the thickness of many thousand feet, I have felt inclined to exclaim that causes such as the present rivers and the present beaches could never have ground down and produced such masses. But, on the other hand, when listening to the rattling noise of these torrents, and calling to mind that whole races of animals have passed away from the face of the earth, and that during this whole period, night and day, these stones have gone rattling onwards in their course, I have thought to myself, can any mountains, any continent, withstand such waste?'

Similar images of destruction occur in every mountain region, for the atmospherical agencies are everywhere working on the naked rock. The enormous masses of boulders which the swollen Alpine torrents sweep down into the valleys as memorials of their prodigious power, attract the attention of every wanderer in Switzerland. The superficial observer sees in these piles of stone only a melancholy picture of ruin; but to him who loves to trace the phenomena of Nature to their source, they are eloquent witnesses of the gigantic and eternal war between the atmosphere and the solid earth.

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[1] 'Journal of Researches.'

BED OF MOUNTAIN TORRENT FILLED WITH BOULDERS.

'From above,' says Tyndall, 'the Matterhorn seems torn to pieces by the frosts of ages, while its vast facets are so foreshortened as to stretch out into the distance like plains. But this underestimate of the steepness of the mountain is checked by the deportment of its stones; their discharge along the side of the pyramid was incessant, and at any moment, by detaching a single boulder, we could let loose a cataract of them, which flew with wild rapidity and with a clatter as loud as thunder down the mountain.

'As long as the temperature of our planet differs from that of space, so long will the forms upon her surface undergo mutation, and as soon as equilibrium has been established we shall have—not peace, but death. Life is the product and accompaniment of change, and the self-same power that tears the flanks of the hills to pieces is the mainspring of the animal and vegetable worlds. Still there is something chilling, if not humiliating, in the contemplation of the irresistible and remorseless character of those infinitesimal forces, whose summation through the ages pulls down even the Matterhorn. Hacked and hurt by time, the aspect of the mountain from its higher crags saddened me. Hitherto the impression it made was that of savage strength, but here we had inexorable decay.'

Rain not only shows its power in the visible fury of the mountain torrent—it also effects disturbances and changes in the surface of the earth in a more insidious and secret manner by undermining the foundations of the land, and causing vast masses of rock to topple down into the plain, or large tracts of ground to slide to a lower level. Filtering through crevices, fissures, or porous strata, it slowly and invisibly prepares the work of destruction, which finally takes place with sudden and irresistible violence, even as the launched ship darts into the water when the stays are removed that kept it in its place. Thus a long continuance of rainy weather caused the fall of the Rufi Berg, which in 1806 buried three villages under its ruins; and going back to ancient history, we read that the once flourishing Roman town of Tauretunum, on the southern bank of the Lake of Geneva, was utterly destroyed in 563 by the disruption of an overhanging mountain.

Two dry seasons in the White Mountains in New Hampshire (United States) were followed by heavy rains on August 28, 1826, when from the steep and lofty declivities which rise abruptly on both sides of the river Saco, innumerable rocks and stones, many of sufficient size to fill a common room, were detached, and in their descent swept down before them in one promiscuous and frightful ruin, forests, shrubs, and the earth which sustained them. Forests of spruce fir and hemlock were prostrated with as much ease as if they had been fields of grain; for where they disputed the ground, the torrent of mud and rock accumulated behind till it gathered sufficient force to burst the temporary barrier.

The glacier also exhibits on a magnificent scale the destructive power of the air over the hardest rock. On its broad back the solid stream, silent but irresistible like fate, carries the huge boulders which the frost and the tempest have riven from the mountain summits far down into the valleys, and heaps them up in prodigious mounds at its foot.

At the same time, it pulverises with grinding force the rock walls over or along which it slides downwards, and troubles with their detritus the stream which gushes from its glacial bosom.

Though frost is the great disintegrator of stone, yet excessive heat has a similar effect. In the Sahara, the rock, expanded by the burning heat of day, contracts in the cooler night air; and, weakened in its texture by these alternating agencies, gives way, and is splintered into fragments, which, finally converted into dust, become the prey of the winds, and are scattered by the simoom over the face of the desert, or even carried far away over the ocean.

STORM WAVES.

Not satisfied with the stone-dissolving power which it displays on the dry land, the atmosphere also forces the ocean to take part in the work of destruction. Its winged servants, the winds, sweeping over the surface of the sea, raise mountain billows, and then fling them with a terrible force against the shore.

Milton, indeed, tells us that

> Surging waves against a solid rock,
> Though all to shivers dashed, th' assault renew,
> *Vain battery*, and in froth and bubbles end.

But however ineffectual their assault may seem when measured by a brief space of time, no rock, however hard, is ultimately able to resist their constantly repeated attacks; one block after another gives way to the triumphant waves, and thus, in the course of centuries, the steep cliffs are finally decorated with picturesque arcades and deep grottoes, in which the seal finds a retreat, and the sea swallow builds her nest. The small island of Heligoland, among others, shows us abundant traces of this everlasting war between the agitated sea and the hard rock which offers it a vain resistance. Not a year passes without the island suffering some loss—here by the fall of some undermined cliff, there by the deepening of a marine grotto; and thus, slowly but surely, the time is approaching when it will be totally whelmed beneath the waves. The sea is to all appearances its chief antagonist, but the thundering breakers are only the agents of the storm that rages over its summit.

The dissolving power of carbonic acid is another assistant of the atmosphere in its constant endeavours to remodel the surface of the earth. Whole mountain ranges consist, as we all know, of limestone, which is corroded by the carbonic acid contained in rain-water. The rain penetrates into the smallest fissures of the limestone rock, enlarges them into passages of constantly increasing width and depth, and ultimately forms, in the course of unnumbered centuries, vast channels, through which, hidden in darkness, the mountain stream rushes along in its subterranean course. Often, in consequence of the progressive corrosion and dissolution of the stone, the nightly river forsakes its first bed, to roll its waters at a greater depth. Thus the Poik once streamed through the celebrated Cave of Adelsberg, and now flows far below in a new channel, and unknown. Thus also the enormous Mammoth Cave in Kentucky was once the bed of the Green River, which has been diverted into another channel. Enormous ranges of limestone rock are in this manner perforated like a sponge by a labyrinth of subterranean passages and caverns whose roof frequently falls in and exposes a yawning abyss to the view. The subterranean destruction performed by the atmospherical precipitations thus finally comes to light, and the sun shines upon the ruins which the air worked out in darkness.

But the disintegration of rocks, which, with regard to the solid scaffolding of the earth, appears as a work of destruction, is the mediator of organic life. All our fruitful plains have been created by the breaking up and deposition of solid stone, which otherwise would have been but a dead waste; and winter which, with the irresistible power of frost, drives its wedges and levers into the finest crevices of the rock, opens the way to the chemical influences of the air, and produces a soft and fertile soil, into which the plants can strike their roots and find an abundance of nutritious salts.

No scene on earth exhibits a more terrible aspect of destruction and death than the lava streams which the volcano pours forth from its breast of fire. For years and centuries its ghastly surface remains, to all appearances, for ever incapable of culture; but the atmosphere, with its perpetual changes of temperature, and its chemical action, is all the time at work, gnawing the solid texture of the lava, and gradually undermining its hardness. To the impatient eye of man, who is but too prone to measure the grand processes of Nature by the short span of his own existence, the progress of the atmosphere appears immeasurably slow; but still disintegration is constantly proceeding, and finally the vine and the chestnut flourish where, on the slopes of Etna or Vesuvius, a petrified sea of barren rocks once showed all the desolation of chaos.

Thus the atmosphere, with its trusty assistant, almighty time, transforms a desert into a paradise, and calls forth new life out of ruins. The great destroyer is at the same time the great beautifier of the earth. It corrodes the brow of the mountains, but it crowns them with verdant forests; it scoops deep channels in their flanks, but adorns them with picturesque rock walls, and all the graces of vegetation; it scatters boulders over the bottom of the dell, but pours over them the foaming torrent, the delight of every lover of

Nature; it loosens the texture of the stone, but prepares the soil for a world of plants, destined in their turn to feed a world of animals; it hurls the breakers of the ocean against the rock-bound coast, but while cliff after cliff yields to the attack, the eye is charmed with a magnificent succession of

ENTRANCE TO THE CAVE OF ADELSBERG.

wave-worn columns and buttresses, of fantastic cornices and bold archways, of dark recesses and projecting headlands.

Even below the surface of the earth the destructive work of the atmospheric agencies is at the same time a work of beauty. The water percolating through the roofs and sides of the limestone caverns invests them with crystal draperies and glittering stalactites, displaying every variety of form which the most luxuriant fancy can imagine; and when, after the lapse of uncounted ages, man discovers one of these hidden temples of Nature, his eye glances over beauties which, though elaborated in darkness, were originally derived from the world of air and light.

Thus, from the highest pinnacles of the earth to its deepest caves, we everywhere meet with the traces of atmospheric influence; but the various structure and configuration of the solid earthrind has in its turn a vast influence over the aerial phenomena. Mountain ranges force the rain to descend over some countries in torrents, while they deprive others of all beneficial showers; they compel the clouds to gather round their brow and change the direction of the winds. The different elevation of the lands, and the dissimilar nature of the soil, such as its dryness, its humidity, and its various heat-absorbing and radiating power, are the causes of constant changes of temperature in the atmosphere which provoke no less perpetual aerial migrations all over the face of the globe.

Though the subject is enveloped in obscurity, there even seems to be a connexion between the state of the atmosphere and the subterranean powers which give rise to the volcanic explosion and the earthquake, the one reacting upon the other.

During the great Neapolitan earthquake of 1857, an unusual halo-like light was seen in the sky before, and not long before, the shock. M. Mallet[1] was at first inclined to look upon this notion as a superstitious tale; but finding it widely diffused in a country where communication is bad, and news travels slowly, he no longer doubted that it was founded on fact. 'Conjectures would be useless as to its nature,' says the eminent seismologist; 'but future observation directed to the point may determine whether some sort of auroral light may emanate from the vast depths of rock formation under the enormous tensions and compressions that must precede the final crash and rupture, or whether volcanic action going on in the unseen depths below may give rise to powerful disturbances of electric equilibrium, and hence to the development of light.' Humboldt is also of opinion that during violent shocks some change may occur in the condition of the atmosphere. Thus, during the earthquake in the Piedmontese valleys of Pelis and Clusson, great alterations were observed in the electrical tension of the atmosphere, without any appearance of a thunderstorm.

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[1] 'The Great Neapolitan Earthquake of 1857,' vol. i. p. 323.

In Northern Chili, where from the extreme infrequency of rain, or even of weather foreboding rain, the probability of accidental coincidences becomes very small, the people are most firmly convinced of some connexion between the state of the atmosphere and the trembling of the ground. When Mr. Darwin mentioned to some people at Copiapo that there had been a sharp shock at Coquimbo, they immediately cried out, 'How fortunate! there will be plenty of pasture, then, this year.' To their minds an earthquake foretold rain, as surely as rain foretold abundant pasture. Certainly, it did so happen that a shower of rain fell on the very day of the earthquake. At other times rain has followed earthquakes at a period of the year when it is a far greater prodigy than the earthquake itself; this happened after the shock of November 1822, and again in 1829 at Valparaiso, also after that of September 1833, at Tacna. 'A person,' says Mr. Darwin, 'must be somewhat habituated to the climates of these countries to perceive the extreme improbability of rain falling at such seasons, except as a consequence of some law quite unconnected with the ordinary course of the weather. In the case of great volcanic eruptions, such as that of Cosiguina, where torrents of rain fell at a time of the year most unusual for it, and almost unprecedented in Central America, it is not difficult to understand that the volumes of vapour and clouds of ashes might have disturbed the atmospheric equilibrium. Humboldt extends this view of the case to earthquakes unaccompanied by eruptions, but I can hardly conceive it possible that the small quantity of aeriform fluids which then escape from the fissured ground, can produce such remarkable effects. There appears much probability in the view first proposed by Mr. P. Scrope, that when the barometer is low, and when rain might naturally be expected to fall, the diminished pressure of the atmosphere over a wide extent of country might well determine the precise day on which the earth, already stretched to the utmost by the subterranean forces, should yield, crack, and consequently tremble. It is, however, doubtful how far this idea will explain the circumstance of torrents of rain falling in the dry season during several days after an earthquake unaccompanied by an eruption. Such cases seem to bespeak some more intimate connexion between the atmospheric and subterranean regions.'

CHAPTER XXVII.

THE ATMOSPHERE AND THE OCEAN.

Relations between the Aerial and Aqueous Oceans—Storm Floods—The Coasts of the Netherlands—Influence of Ocean Currents on the Atmosphere—The Gulf Stream—Its Beneficial Influence on the Climate of Great Britain—The Peruvian Stream—Influence of Barometric Pressure on the Rise and Fall of the Sea —The Cyclone Wave—Its dreadful Effects.

THE air and the ocean are constantly mingling their constituent parts, and to this interchange all that lives and breathes on earth, from the high soaring eagle to the grovelling mollusc, and from the Alpine rhododendron to the submarine fucus, is indebted for its existence. For out of the bosom of the immeasurable deep arises the aqueous vapour which maintains the life of all the terrestrial plants and animals; while the sea, in return for the gifts it bestows, is constantly absorbing air which provides the fishes with the oxygen as necessarily required for their existence as the beings which breathe in the atmosphere itself.

Supposing the aerial and aqueous oceans incapable of mingling their contents, and as mutually repulsive as oil and water—then all life vanishes in the heights of the atmosphere and in the depths of the sea, and the whole earth becomes a melancholy waste, while now their constant tendency to invade each other's domains furnishes the means of existence to that wonderful variety of organic forms which adorns and enlivens the terrestrial globe.

Another highly important relation between the two oceans which encompass the solid earth is the influence they exert upon each other's movements. The refreshing breezes which along our coasts so delightfully mitigate the summer's heat are due to the coolness which the sea imparts to the atmosphere, and it is the wind which causes the wave to swell so gracefully when a light zephyr curls the surface of the ocean, and with such awful grandeur when the hurricane raises its waters to mountain billows.

Every humour of the atmosphere is thus reflected by the ocean; all its changes produce an analogous change in that faithful mirror.

Waves, the children of the wind, become its terrible auxiliaries in the work of destruction when the combined genii of the ocean and the air rage against the dykes or sand dunes of a low coastland. Then, indeed, man is made to feel his weakness, and stands aghast at the irresistible fury of the elementary powers.

On December 30 and 31, 1789, one of these dreadful storm-floods devastated the coast of Flanders. The roar of the ocean was heard at the distance of five and twenty miles, and united its loud voice with that of the wind which shook the Abbey of Ravensberg in spite of its solid walls. At Amsterdam the water of the Y river rose fifty-six inches above its ordinary level, and considerable damage was done at Deal on the opposite coast of England. A similar storm still more terrible in its effects, from the simultaneous spring tide, raged on January 14, 1808, on the coasts of Holland and Belgium. Bruges was completely inundated; in the environs of Ghent the destruction of the dykes caused 20,000 acres of land to be overflowed, and in one of the streets of Antwerp twenty-nine persons were drowned.

In 1872 one of those dreadful floods whose devastations attain the dimensions of a national disaster covered the coasts of the Baltic with ruins. Impelled by a furious gale from the north-east, which raged for several days with constantly increasing fury, the waters of that inland sea accumulated in the narrow estuaries, friths, and channels which intersect the coasts of Pomerania, Schleswig-Holstein, and Denmark, and, bursting the dykes, poured their resistless floods over the land. The small town of Eckernförde, in Schleswig, was almost completely ruined. Whole streets were literally swept away from the face of the earth, so that after the disaster it was difficult to point out the sites on which the single buildings had stood. More than a hundred houses were utterly destroyed, and the foundations of others, which had resisted the shock of the waves, were so undermined by the waters that they afterwards fell in, or were obliged to be pulled down.

In the island of Fehmarn, the greater part of which was under water, the family of a pilot—man, wife, and children—which had sought a refuge from the inundation on the roof of the house, was overwhelmed and lost in the waves, along with the fallen building. A Norwegian brig bound for a Schleswig port was driven by the gale against the coast, and, instead of entering the hospitable harbour, struck in the darkness of the night against a submerged village. The crew clambered over the roofs, when one of the sailors slid down from the tiles and was drowned. A French brig which entered the harbour of Kiel when the storm had abated, brought in a boy—the last remnant of his family—whom it had found in the sea, floating on a roof.

Such and similar scenes of death and destruction occurred along many hundred miles of coast; incalculable damage was done to towns, villages, and farms; vast tracts of arable land or fertile meadows were buried under unfruitful sand; and the total loss estimated at many millions of dollars. All this occurred on a dreadful November night, leaving the thousands whom it had reduced to penury and want with the cheerless prospect of the long cold winter of the north.

The annals of past centuries afford us instances of still greater devastations occasioned by the floods of a sea goaded to madness by a furious gale. The storm which, on November 19, 1421, raged against the coasts of the Netherlands, destroyed seventy-two villages, and caused the death of more than 100,000 persons; and on November 22, 1686, twenty-five villages and 10,000 victims were destroyed by a similar catastrophe. 'Whilst reading these accounts, we are led to compare the inhabitants of the Dutch lowlands with those of the fertile fields and vineyards that clothe the sides of Vesuvius—both exposed to sudden and irretrievable ruin from the rage of two different elements, and yet both contented, and careless of the future—the first behind the dykes that have often given way to the ocean, the latter on the very brink of a menacing volcano.'[1]

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[1] 'The Sea and its Living Wonders,' p. 35.

Fortunately, the disasters caused by storm-floods are limited in extent, and of rare occurrence; while the beneficial influence of the sea as a moderator of climate is constant, and extends over a considerable part of the earth.

Comparing equal weights, the specific heat of water being 1°, that of air is about 0·25°. Hence a pound of water, in losing 1° of temperature, would warm four pounds of air 1°. But water is 770 times heavier than air; hence, comparing equal volumes, a cubic foot of water, in losing 1° of temperature, would raise $770 \times 4 = 3{,}080$ cubic feet of air 1°. The heat of summer is thus stored up in the ocean, and slowly given out during the winter.

Wherever tropical ocean currents flow from lower to higher latitudes, they show the genial influence of the enormous quantity of heat they gradually impart to the atmosphere, but nowhere more conspicuously than on the coasts and islands towards which the Gulf Stream directs its course. As is well known, the origin of this magnificent current must be sought for in the action of the trade winds, which, constantly blowing from east to west across the broad bosom of the Atlantic, drive before them a vast surface sheet of hot water, 4,000 miles long by 450 miles broad, at an average rate of thirty miles a day. Off the coast of Africa, near its starting-point, to the south of the islands of St. Thomas and Anna Bon, this 'equatorial current' has a speed of forty miles in the twenty-four hours, and a temperature of 23° C. Increasing in bulk, and spreading out more and more on both sides of the equator, it flows rapidly due west towards the coast of South America, where it divides into two arms at Cape St. Roque. The one flowing to the south conveys some of its warmth as far as the Falkland Islands and Cape Horn, while the northern portion follows the north-east coast of South America, gaining continually in temperature under the influence of the tropical sun. Flowing slowly through the whole length of the Caribbean Sea, and following the contours of the Mexican Gulf, its main current then passes through the Strait of Florida, whence it issues as the Gulf Stream in a vast body of tepid water upwards of 30 miles broad and 2,200 feet deep, with a temperature of 83°. Its initial velocity, as it expands into the ocean on its northward progress, is so great that it traverses the whole distance from the Strait to the Bank of Newfoundland in less than forty days. During this first part of its course it is one of the grandest natural phenomena on earth. The water is clear as crystal, and intensely blue, and long after it has passed into the open sea it keeps itself apart, easily distinguished by its warmth, its colour, and its clearness, and with its edges so sharply marked that a ship may have her stem in the clear blue stream, while her stern is still in the common water of the ocean.

Numerous marine animals of the tropical seas—the flying fish, the velella, the purple ianthine, the crosier nautilus—accompany it into regions which otherwise would prove fatal to their existence, and enjoy far to the north the mild temperature of their native waters.

Receding farther and farther from the coast of America as it advances on its northern course, the Gulf Stream bends to the east after reaching the forty-first degree of latitude, gradually diminishing in swiftness, and at the same time increasing in width. Thus flowing across the Atlantic, and spreading its waters more and more as far as the Azores, a part of it now turns southwards again towards the African coast, but a great part is carried, both by its own motion and by the prevailing west and north-west winds, towards the coasts of Europe, and even beyond Spitzbergen and Novaya Zemlya.

The following figures give some idea of the quantity of heat it conveys to the northern regions. Mr. Croll[1] estimates the Gulf Stream, after its outflow through the Strait, as equal to a stream of water fifty miles broad and a thousand feet deep, flowing at the rate of four miles an hour, and consequently conveying 5,575,680,000,000 cubic feet of water per hour, or 133,816,320,000,000 cubic feet per day. This mass of water has a mean temperature of 64·5° (?) as it passes out of the gulf, and on its northern journey it is cooled down to 40°, thus losing heat to the amount of 24·5°. Seven pounds of this water, consequently, part with as much heat on their passage to the higher latitudes as would suffice to lower the temperature of one pound of water from boiling heat to zero. It has been calculated that the total amount of caloric thus conveyed to the north is nearly equal to the whole of the heat received from the sun by the arctic regions; and reduced by a half, to avoid all possibility of exaggeration, it is still equal to one-fifth of the whole amount received from the sun by the whole area of the North Atlantic.

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[1] 'On Ocean Currents,' 'Philosophical Magazine,' Feb. 1870.

The warmth of the Gulf Stream diffusing itself in the atmosphere, and carried by the prevailing winds to the shores of North-Western Europe, thus fully accounts for the remarkably mild climate enjoyed by countries which their distance from the equator would otherwise have doomed to all the rigours of the arctic zone, and, as might be expected, its influence makes itself most evident in the season when the meridian sun stands lowest above the horizon. It thus entirely abolishes the difference of temperature due to the difference of latitude of north and south Britain; if we walk from the Channel to the Shetland Isles in January, we encounter everywhere the same temperature.

It is owing to the Gulf Stream that in Tipperary the laurel growing in the open air and without cover during the winter attains a height of twenty or thirty feet; that the tree of Apollo flourishes in the isle of Bute, and is even met with as far north as Thurso, though here only as a shrub. Still nearer to the pole, the Gulf Stream keeps the harbours of Talvig and Hammerfest free from ice all the year round, and along the coast of Norway it allows the birch and the fir-tree to climb the mountain slopes to a height of 700 or 800 feet above the level of the sea as far as the seventieth degree of latitude.

On the opposite shores of America, where no warm current exerts its influence, we find a totally different climate. The river Hudson, for example, in the latitude of Rome, is frozen over for three months in the year; and Labrador, which fronts the British Isles, is a region of almost perpetual winter.

The contrast between northern Europe and the east coast of America caused Halley to surmise that the north pole of the earth had shifted; that it was formerly situated somewhere near Behring's Straits, and that the intense cold observed in these regions is really the cold of the ancient pole, which had not been subdued since the axis changed its direction. But now we no longer seek its origin in fanciful revolutions, for we know that the Gulf Stream and the diffusion of heat by winds and vapours are the real causes of European mildness.

On the western coast of America we find a warm ocean current producing similar effects. The equatorial stream of the Pacific,[1] driven by the trade winds across the bosom of that vast ocean, divides into several branches on its western banks. Part of its waters flow to the south, but the remainder, turning to the north-east, passes along the eastern coast of the Japanese islands, and then spreads its warm waters under the influence of north-westerly winds over the northern part of the Pacific. These winds, warmed by its contact, endow Sitka with a mean annual temperature of +7° R., while on the Atlantic shore of North America it falls to −3·6° under the same latitude. On the west coast of North America the analogous trees grow 3° or 4° nearer to the pole, and the aboriginal tribes go naked as far as 52° N. lat.—a simplicity of toilet that evidently would but ill suit the Esquimaux of Labrador.

In other parts of the globe cold currents flowing in an equatorial direction produce the opposite effects. Thus the Peruvian stream which issues from the Antarctic Ocean laden with icebergs and drift ice, reduces the temperature along the west coast of South America; and the cold arctic current which flows from the coasts of Greenland towards Labrador and Newfoundland accounts for the wretched climate of these inhospitable lands.

Among the influences which the atmosphere brings to bear upon the ocean, we have finally to notice that of its varying pressure. As the barometer rises or falls, it causes the surface of the sea to fall or rise; for wherever a greater weight rests upon the ocean, it must necessarily force the water (though almost incompressible in itself) towards some other part where a smaller pressure exists for the time. Thus the ocean continually oscillates up and down with every caprice of the atmosphere, even as the column of mercury oscillates in the barometer, and obeys the constantly changing pressure of the air. These oscillations, which generally pass away unheeded, and without any observable effects, are sometimes the causes of appalling catastrophes.

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[1] 'The Sea and its Living Wonders,' p. 63.

We have seen in a previous chapter that a very considerable diminution of atmospheric pressure takes place on the passage of a cyclone, causing a rising of the sea wherever the storm sweeps over its surface. For every inch which the barometer falls the water rises a little more than a foot, so that in the open sea the height of the cyclone wave probably seldom exceeds two feet. But still, in consequence of its considerable breadth of several hundred sea miles, this wave contains an enormous mass of water; and, though harmless as long as no obstacle impedes its free progress and expansion, it rises to a terrific height when the direction taken by the cyclone causes it to undulate into a gradually narrowing bay. In the East Indies, Coringa, on the coast of Coromandel, has several times been destroyed by these tremendous swellings of the ocean. Thus, in December 1789, the unfortunate inhabitants saw during a dreadful storm three enormous waves advancing from the sea. The first wave swept away everything before it, and laid the town several feet under water; the second increased these devastations by inundating the whole of the flat country; and the third completed the universal ruin.

The town and 20,000 of its inhabitants disappeared; the ships were torn from their anchors, and cast high upon the land. When the sea returned within its usual bounds it left masses of sand and mud behind which made the search after property and corpses utterly impossible.

In June 1822, Burisal and Backergunge, at the mouths of the Ganges, were inundated, and 50,000 persons were drowned in the gradually rising storm-flood. Piddington ascribes the great rise of the water partly to the very slow progress of the cyclone, which advanced at the rate of two sea miles per hour. On May 21, 1833, 300 villages at the mouth of the Hooghly were destroyed by a dreadful wave, which rose nine feet above the highest dykes, and drowned 50,000 persons.

In order to find similar instances of widespread death and devastation suddenly befalling the population of whole cities, we must turn to the records of the earthquake, where we read of large towns levelled to the dust by a single shock, or look far back into the pages of history, where Tacitus[1] relates the falling-in of the amphitheatre of Fidenae, which buried 50,000 persons under its ruins—'An unforeseen calamity,' says the great annalist, 'equalling the carnage of great wars.'

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[1] 'Annalium,' lib. iv. 62: 'Ingentium bellorum cladem æquavit malum improvisum.'

CHAPTER XXVIII.

THE ATMOSPHERE AND THE VEGETABLE WORLD.

Action of the Winds—Moisture and Warmth the great Promoters of Vegetation—Their Influence in the Tropical Regions—Zones of Vegetation—Effects of the Wet Climates of Chiloe and Sitka—Newfoundland—Rainless Tropical Countries—Change of Vegetation Produced by Elevation—The Vegetative Zones of Etna—Climates Appropriate to Different Families of Plants—Analogous Climates Produce Everywhere an Analogous Vegetation—The Seasons in the Temperate Zone, and in the Equatorial Regions—The Winds as Disseminators of Plants—Influence of Forests on Climate—Their Rain-attracting Power—Forest Voices.

THE atmosphere is the parent and sustainer of all vegetable life; for, if our earth were deprived of its aerial ocean, its surface, like that of the moon, would be a mere waste of naked rocks.

From the atmosphere the plant receives the gaseous substances it requires for its growth; from this source it derives the moisture, without which it would droop and perish; the air warmed by the sun gives it the temperature congenial to its nature; and the winds bear along with them its sporules, its pollen, or its seeds, and serve as the mediators of its propagation and diffusion over the earth.

But moisture and warmth—the great promoters and quickeners of vegetation—are very unequally distributed over the surface of our globe. In some countries, we find an almost perpetual winter; in others, an everlasting summer; here the temperature is constant, there it is subject to incessant changes; and while the sluices of the skies are almost always open in some places, fertilising showers are an unknown phenomenon in others.

Thus, from the poles to the equator, the plants meet with an enormous variety of climates, and this produces that no less enormous variety of forms of vegetation which delights the eye and fills the mind with admiration.

As might be expected, Flora displays her utmost prodigality of growth in the equatorial zone (between 15° N. lat. and 15° S. lat.) where an abundance of moisture is coupled with a constant high temperature. Here the vegetation is chiefly characterised by the forms of palms, bananas, arborescent grasses, screw pines, orchids, mimosas, and bush-ropes. In the primeval forests we meet with cotton trees (*Bombaceæ*) whose gigantic trunks are often covered with thorns and large wart-like excrescences, and fig-trees which likewise grow to an enormous size. Here also the greatest variety of form and colour prevails. The leaves and blossoms are larger and more lustrous than elsewhere. The numerous bush-ropes forming an intricate network from tree to tree, like the cordage of a ship, are likewise a characteristic of the equatorial woods.

While our oaks and beeches show but a scanty covering of scurfy lichens or small mosses, the rind of the tropical trees is decorated with long-leaved bromelias and wondrous orchids. Sweet-smelling vanillas and passion-flowers climb along the trunks of the giants of the forest. Large blossoms burst forth from rugged barks and roots. The tepid waters of the lagunes and rivers produce leaves and flowers of an enormous size; and a single tree of the primeval forest often bears such a host of parasites and creepers, that if they were spread out they would cover a considerable surface of ground.

'When,' says Brehm,[1] 'the wanderer towards the equator passes the eighteenth degree of northern latitude, and enters the region of the rains which swell the tributaries of the Nile, he soon perceives their mighty influence. The sandy wastes disappear; the dusty plains on which he saw as yet but arid reeds begin to clothe themselves with the first signs of verdure; and even in the crevices of the glowing rocks there is a manifest eagerness of vegetation to expand in leaves and blossoms.

'On advancing towards the south the number both of species and of individual plants increases. Already under the sixteenth degree of northern latitude the mimosas, which hitherto grew singly, and as shrubs, on the banks of the rivers, crowd together into forests, and are transformed into large umbrageous trees. Every degree which brings us nearer to the line shows an increasing rainfall, and a corresponding richness in the growth of plants.'

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[1] 'Reiseskizzen in Nord-Öst Afrika.'

The tropical zone, extending from 15° to 23·5° N. and S. lat., shows a vegetation similar in general to that which prevails in the countries nearer to the line, but of a less exuberant character. Meyen[1] calls it the region of dendritic ferns and fig-trees. The forests in this belt are richer in underwood; those nearer the equator in bush-ropes and creeping plants.

The subtropical zone, or the region of myrtles and laurels, extends from 23·5° to 34° N. and S. lat. In many parts, tropical plants, such as palms, bananas, and arborescent grasses, are still met with. Here, however, a marked difference between summer and winter begins already to show itself; the latter, however, being still so mild that vegetation is not suspended. But the changes of temperature in the course of the year bring about a change in the flora, while in the above-mentioned equatorial and tropical zones, the different proportions of moisture are the chief causes of differences of vegetation, as the temperature varies but little throughout the year. Trees with thick, leathery, and shining leaves are very common in this zone.

The warmer temperate zone (from 34° to 45° N. and S. lat.) is, like the former, characterised by evergreen trees, with thick leathery leaves, though others of a more delicate foliage begin to appear upon the scene. The chief forms are oaks, beeches, chestnut and walnut trees, ashes, plantains, laurels, olives, the tea plant, vines, orange and almond trees, roses, liliaceous plants, shrub ferns, cypresses, myrtles, &c.

The colder temperate zone (from 45° to 58° N. and S. lat.), or the region of trees with deciduous foliage, comprises Great Britain and Ireland, the northern provinces of France, all Germany, the southern part of Sweden, Poland, Hungary, South Russia, North Turan, the Altaiĉ Regions, and Mandschuria, Kamtschatka, the lands to the north of Mexico, and the United States as far as the southern shores of Hudson's Bay, with Canada and Labrador. In the southern hemisphere Patagonia, Fuegia, and the Falkland Islands, belong to this zone.

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[1] 'Grundriss der Pflanzengeographie.' Berlin, 1836.

Trees with broad thin leaves are prevalent in these countries; but the coniferous plants also become more and more common. The trunks of the forest trees are covered with mosses and lichens. The chief creeping plants are hops, ivy, and lonicera. Low grasses, growing usually in considerable masses, and forming extensive meadows, appear. The winter suspends vegetation. The northern border of this zone (58° N. lat.) coincides in Western Europe with the polar limits of the beech tree, while the Ural mountains form the eastern limits of the oak. In America the polar boundary of most of the cereals falls within this zone.

The subarctic zone (from 58° to 66·5° N. and S. lat.) is the region of coniferous plants. Pines, larches, firs, willows, birches, are its characteristic trees. In South Greenland, and Iceland the potato is still cultivated; in Europe, oats, barley, rye, wheat, buck-wheat, tobacco, flax, hemp; in Siberia, oats, potatoes, barley. Meadows with low grasses are still met with, but the reeds increase in numbers as well as the lichens and mosses.

The arctic zone (from 66° N. lat. to 72°) still produces pines and firs, at least in Europe. The birch forms the extreme limit of arboreal vegetation. Meadows become very rare, while large tracts of ground are covered with mosses and arid lichens. Low shrubs are also still met with. Cultivated plants, such as turnips, cabbages, potatoes, and barley, are only met with in Europe.

In the polar zone (from 72° to the poles), as far as man has penetrated in that direction, vegetation is reduced to its scantiest limits, and merely creeps upon the ground. Trees and shrubs are completely wanting. For want of water and a loose soil, large spaces are completely naked. During the short summer only a few Alpine herbs bring forth blossoms.

When a comparatively mild temperature combines with frequent rains, the woods of the temperate zone show the effects of moisture and of a moderate warmth in the stateliness and vigour of their growths. On the south-west coast of America, for instance, where the climate is remarkably equable and humid, the native forests (from 45° to 38° S. lat.) almost rival in luxuriance those of the glowing intertropical regions. Noble trees of many kinds, with smooth and highly-coloured barks, are loaded with parasitical plants; large and elegant ferns are numerous, and arborescent grasses entwine the trees into one entangled mass to the height of 30 or 40 feet above the ground.[1]

On the island of Sitka, and on the conterminous coasts of North America, we meet with a similar climate and equally impervious forests. The ground is covered with innumerable trunks of trees felled by the storm or mouldering with age, which for centuries have formed the soil of these primeval woods. In the more or less deep intervals between the prostrate giants a world of smaller plants luxuriates in the shade of the mighty pines, whose bark is covered with colossal cushions of mosses, and from whose branches the usneas hang down in long festoons. Out of the decaying trunks grow forth not only large shrub-like vaccinias and high picturesque tufts of grasses, but numerous young forest trees—so that the death of one generation gives life to another.

It is almost impossible to penetrate into these tangled woods. Kittlitz, who made the attempt, was so fatigued by perpetually climbing over the fallen and more or less rotten trunks, by creeping under their numerous interlacing branches, and by incessantly sounding the intermediate hollows hidden under a dense carpet of low shrubs and treacherous mosses, that he was almost obliged to remain lying in the woods from sheer exhaustion.[2]

The moist and equable atmosphere of Newfoundland produces a similar vegetation, though here, in consequence of a bleaker climate, the wood is generally of low and stunted growth. The trees commonly grow so closely together that their twigs and branches interlace from top to bottom, and lying indiscriminately amongst them there are innumerable old and rotten stumps and branches or newly-fallen trees, which, with the young shoots and brushwood, form a tangled and often impenetrable thicket. The trees are often covered with lichens, and tufts of white dry moss are entangled about the branches. Other green and softer mosses spread over the ground, concealing alike the twisted roots of the standing trees and the pointed stumps of those which have fallen, the sharp edges or slippery surfaces of the numerous rocks and boulders, and the holes and pitfalls between them. Every step through these woods is a matter of toil and anxiety, requiring constant vigilance to avoid falling, and constant labour to procure standing-room; climbing and creeping, and every mode of progression, must be had recourse to, and new directions have constantly to be taken in order to find the most practicable places through which to force a slow and tortuous way. Embosomed in the woods are open tracts covered with moss to a depth sometimes of several feet. This moss is soft, green, and spongy, and is bound together by straggling grasses and various marsh plants.

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[1] Darwin, 'Journal of Researches.'

[2] Kittlitz, 'Reisen nach dem russischen Amerika.'

It may be imagined how difficult travelling must be in a country like this. A march of a few hours, sinking at every step into the moss, sometimes knee-deep and always as far as the ankle, is enough to task the strength of the most robust pedestrian. This thick coating of moss is precisely like a great sponge spread over the country, and becomes at the melting of the snow in the spring thoroughly saturated with water, which it long retains, and which every shower of rain continually renews.[1]

With the copiously irrigated forest-lands above described the rainless Peruvian coast or the arid plateaux of New Mexico form the completest contrast. Here plants meet with a far less favourable climate, for though warmth abounds, the necessary moisture for luxurious growth is wanting; but here also vegetation accommodates itself with an admirable flexibility to circumstances, and appears in new and wondrous forms. In the most arid and meagre soil, on stones and rocks, the singular cactus family thrives in hundreds of species, which, by their remarkable type, impart a peculiar character to all the countries where they form the predominant vegetation. Admirably constructed by their juicy tissue for withstanding a drought of many months, they might be compared with the camel, who finds in the peculiar organisation of his stomach a powerful means for sustaining a long-continued penury of water. It is chiefly through their leaves that plants evaporate, and the cactuses have no leaves. Their stems, moreover, differing from those of all other plants, are covered with a peculiar leathery skin, which almost entirely prevents evaporation. This skin is thickest, and consequently most impenetrable, in the melon cactuses, which grow in the hottest and most arid situations, and fully enables them to withstand for months the rays of the scorching sun.

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[1] Jukes, 'Excursions in Newfoundland.

In mountainous regions, where a change of climate takes place with every increase of altitude, the traveller, as he ascends into a colder and more rarefied atmosphere, meets with changes in the world of plants similar to those he would have experienced on wandering from lower to higher latitudes.

On journeying along the Reuss, for instance, from the Lake of Lucerne to the Valley of Urseren, the Alpine wanderer sees in a few hours the finest walnut-trees replaced by the stunted dwarf pine, which, clinging to the grey rock, is alone able to resist the wintry blast. But nowhere in Europe is the influence of altitude on climate, and consequently on the growth of plants, more striking than on Mount Etna, which rises from the warm shores of the Mediterranean to beyond the limits of perpetual snow. Here the different zones of vegetation are so distinctly marked that the inhabitants of the country, though without any idea of the geography of plants, have divided the mountain into three natural regions.

The cultivated zone, which extends from the foot of the mountain to a height of 2,500 feet, enjoys an almost tropical vegetation. Here the vine and the olive, the almond and the fig-tree, grow in luxuriant abundance; here even the cotton-plant and the sugar-cane thrive along with the finest wheat and barley. Where the young lava has poured its rugged streams into these happy fields, and the hard stone is still undecomposed, the Cactus Opuntia, or Indian fig, which has found its way from America to the classical shores of Etna, forms the characteristic plant, and finds a congenial climate on the sun-burnt, rocky ground.

In the woody region, which extends from 2,500 to 6,000 feet, the orange and olive-trees no longer grow, and gradually the vine, the almond, and the fig-trees disappear. In the lower part of this zone, which is extolled by Brydone as one of the most delightful spots on earth, the woods consist principally of large chestnut-trees and oaks with a deciduous foliage. Higher up, these trees are replaced by the beech, a species of pine, and the birch, which on ascending grow gradually less, and at last degenerate into the small plants of the northern climates. The cereals, which are cultivated lower down, entirely disappear in the upper part of this region. A species of broom encircles the whole woody zone as a characteristic shrub.

In the frigid or desert region vegetation is extremely monotonous and sparing, from the want of springs or rivulets and the rocky nature of the soil. The lower part still shows some signs of verdure in stunted bushes of the sloe and the juniper; but from 7,501 feet to the summit these also disappear, and scarce ten species of herbs are to be found, among which our common tansy and Senecio chrysanthemifolius are the most conspicuous. Such is the poverty to which elevation has reduced the prodigal exuberance of the cultivated region.

Still more marked are the successive changes of vegetation displayed on the slopes of the Andes or of the Himalaya, where the scale begins with palms and ends with the scanty productions of the polar zone; where to-day the traveller wanders under the centenary giants of a tropical forest, and sees to-morrow the last traces of vegetation expire on the verge of perpetual snow.

'The extraordinary height,' says Humboldt, 'to which in the tropical regions not only single mountains but whole extensive countries are raised, and the low temperature which is the consequence of this elevation, afford a remarkable spectacle to the inhabitants of the equatorial zone. Besides the palms and bananas, he is also surrounded with forms of plants more specially belonging to northern lands. Cypresses, pines, oaks, and alders, closely related to our indigenous species, cover the mountain plains of South Mexico as well as the Andes chain under the Equator. Thus Nature has awarded to man in the torrid zone the privilege of seeing every form of vegetation on earth without quitting his native country, as the firmament from pole to pole conceals none of its luminous worlds from his view.'

Each family of plants has its own peculiar climate in which it attains its highest development. Thus arborescent grasses form one of the chief ornaments of the tropical lands. Our alders and oaks are surpassed in height by the gracefully tapering culms of the bamboos, which unite the elegance of our meadow grasses with the lordly growth of the Italian poplar. On advancing towards higher latitudes the grasses keep constantly diminishing in size with the decreasing power of the sun, until finally the short summer of the arctic zone produces but a few dwarfish specimens.

The contrary takes place with the family of the cold-loving coniferæ, which would have been almost totally unknown within the tropics if many equatorial countries did not attain a considerable altitude. Their perpetual verdure enlivens the winter of the north, and their presence generally indicates a climate where a cooler atmosphere and rougher winds reign during the greater part of the year.

While under the line they form the upper limits of arboreal growth, we see them descending lower and lower, or advancing towards the poles, until at length their forests cover the boundless plains of Siberia and Northern America with an almost continuous girdle. From the dreary wilds of Fuegia they creep along the slopes and crests of the Andes and the Rocky Mountains down to the lowlands of the Mackenzie. On the Himalaya, at heights surpassing that of Mont Blanc, they are welcomed by the European traveller as a friendly remembrance of his distant home; they look down from the coast of Norway upon the fiords of the Arctic Ocean, and they gaze from the mountains of Kamtschatka upon the boundless Pacific.

The immense influence of climate on the production of particular forms of plants is shown by the striking similarity of the vegetation in countries situated far apart but subject to similar atmospherical conditions. On his visit to the glaciers of Mont Blanc, the French naturalist Martins fancied himself once more among the icy wastes of Spitzbergen—the same naked rocks and vast snow-fields, the same solitude where no trace announces the existence of man. But the illusion was rendered still more complete when on the rocks of the Jardin he met with the same flowers—the snow ranunculus and the snow saxifrage—whose rare appearance had years before delighted him in the arctic wildernesses.

Immense tracts of land and sea are interposed between the rainless districts of Mexico or Peru and the African deserts, and yet the vegetation of both has the same physiognomical expression. In the parched plains of both hemispheres high-stemmed aloe plants, crowned at the top with a bushel of thick, fleshy, radiating leaves, impart a peculiarly melancholy character to the country. In America we find the agave, from whose sap the Mexican prepares an intoxicating beverage; and near the Red Sea the aloe, the milky juice of which furnishes a well-known drug. The African euphorbias, branching out into thick, short candelabras, resemble in their habit the large columnar cactuses of the rainless Peruvian coast; and the dragon-tree of the Canaries reminds one of the Pitcairnias of the Andes or of the Yuccas of Florida. The traveller, whenever he enters a country where plants like these characterise the vegetation, can at once conclude from their appearance that the climate must be warm and subject to long and frequent droughts.

To judge, however, of the dependence of plants on atmospherical influences we need not wander far and wide, for in our own home the changes of the seasons are constantly bringing it before our view. In winter we see all vegetation cease, and our trees and shrubs, deprived of their foliage, stretch out their naked branches to the sky. But the mild air of spring soon reawakens their dormant life, and decorates them with bright green leaves and sweet-smelling blossoms, whose fruits ripen with the increasing warmth of summer. In autumn, when the days grow shorter and the sun begins to lose its power, the sere and yellow leaf shows that the vital process of plants is again on the decline, and that the period is at hand when it will once more fall into its wintry sleep.

As in the temperate zone the changing seasons call forth corresponding changes in the life of plants, so also in the tropical countries the contrary influence of the dry and moist periods of the year reflects itself in the different conditions of vegetation.

The continuous drought produces phenomena similar to those which arise in Europe from the cold of winter, for vegetation is equally brought to a standstill by the want of moisture and by that of warmth. The calcined grass of the savannah is then as naked as the treeless tundra of the north, and the dull foliage of the woods announces that the dryness of the heated atmosphere reduces the life of plants to the same low ebb as the cold of winter in higher latitudes. But scarcely has the first shower provided tropical vegetation with the element necessary to its growth, when it awakens from its torpor as the vernal sun awakens our plants from their hibernal sleep.

The winds that gently rustle in the foliage of the trees frequently also bow down their crowns to the earth when they sweep over the land with stormy violence, and menace the existence of the plants to which they are generally friendly by a constant renewal of the air. To guard themselves against these hostile attacks our forest trees plunge their roots deep into the earth, and are thus enabled to defy the roaring blast. The conflict between the storm and the centenary monarchs of the woods affords a highly interesting spectacle. Groaning, they bend before the violence of the wind, but as constantly raise themselves again, until finally their untiring and stubborn resistance gains the victory over their furious but short-lived adversary.

When we consider the enormous surface which a giant tree exposes to the hurricane, its huge arms ramifying into hundreds of branches, and its crown towering to the skies, we justly admire the prodigious strength of the trunk, which does not break down under such dreadful assaults, and the inflexible firmness of the roots, which triumph over the enormous strain.

While most plants have been formed for a life divided between darkness and light, being partly anchored in the ground and partly exposing their branches to the warming sunbeam and the playful breeze, the tropical orchids lead a completely aerial life. Reposing on the bark of the primeval forest trees, they may perhaps derive a small portion of their sustenance from the plant to which they cling, but by far the greater part of the materials on which they live is derived from the moist and warm atmosphere of the woods in whose shade they thrive. Suspended in the damp air their long white roots suck up the nourishing gases, and find in its humidity all the substances they require for their growth.

ORCHIDS GROWING ON DEAD TRUNK.

The action of the winds in promoting the dispersion of plants over the surface of the earth is beautifully assisted by the formation of the seeds which are destined to be thus wafted through the air. Many are rendered buoyant by their lightness, others are provided with feathery appendages or wing-like processes, so that the slightest breeze bears them along on their aerial voyage.

While the climate of a country determines the character of its vegetation, we find on the other hand the forests exerting a considerable influence on the condition of the atmosphere. The thick layer of humus formed by the successive falling of their foliage attracts and retains humidity like a sponge, and prevents even on a sloping surface the rapid flowing off of the rain-water, while at the same time their leafy canopy retards evaporation by keeping off the wind and the sun from the soil.

Under their shade the heat of summer is mitigated, and as the humidity which the roots imbibe from the earth is exhaled in the form of vapour by the leaves, the atmosphere over forests is always more moist and nearer to the dew-point than the air over treeless plains. Thus Boussingault[1] found in tropical South America the mean temperature of cleared land nearly four degrees higher than that of forest land. He also observed that seldom a night passes where the dew does not trickle from the trees. 'The night from July 4 to July 5, 1827,' writes this distinguished chemist, 'was magnificent. Nevertheless, it was raining copiously in the forest close to our bivouac. By the light of the moon we could distinctly see drops of water dripping from the branches.'

The rain-attracting power of forests did not escape the attention of Columbus, who ascribed the frequent showers that refreshed and cooled the air as he sailed along the coasts of Jamaica to the vast extent and density of the woods which at that time covered the mountains of the island. On this occasion he mentions in his journal that formerly rain had been equally abundant in Madeira, the Canaries, and the Azores, before their shady forests were felled or burnt by the improvident settlers.

The wanton destruction of woods has entailed barrenness on countries renowned in former times for their fertility. The mountains of Greece were covered with trees during the great epoch of her history, and the well-watered land bore abundant fruits, and sustained a numerous population. But man recklessly laid waste the sources of his prosperity. Along with the woods many sources and rivulets disappeared and ceased to supply the plain with perennial moisture. The rain gradually washed away the vegetable earth from the slopes of the naked hills, and condemned them to sterility. When the snow of the mountains began to thaw under the warm breath of spring, it was now no longer retained by the spongy soil of the forests, but, rapidly melting, filled with its impetuous torrents the bed of the rivers, and, overflowing their banks, spread ruin and desolation far around.

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[1] 'Rural Economy,' translated by Law, p. 667.

In Barbados we are told that, in consequence of the extirpation of the forests, frequently not a drop of rain falls in three years. In St. Helena, on the contrary, the quantity of rain has increased in the same proportion as new woods have been planted, so that it is now about the double of what it was while Napoleon I. resided in the island. In Upper Egypt the formerly copious rains have ceased since the Arabs have felled the trees along the borders of the valley of the Nile. On the other hand, rain has become more abundant in Lower Egypt, at Cairo and Alexandria, in consequence of the extensive plantations that have been made in the environs. In Malta, again, the trees have been felled to make room for the increased cultivation of cotton, and since then the rain has very much diminished. The department of the Var in the south of France possessed numerous rivulets and sources; but in the year 1821 the olive trees, which from their number almost formed continuous woods, were frozen and afterwards felled. A drying-up of the sources was the consequence.

'In the hot regions of the earth,' says Dove,[1] 'we have evident proofs of the devastating influence of what is called cultivation of the land. The islands of Cape Verde, and the Canaries, where the primeval forest fell under the axe of the first settlers, or the Azores where it was burnt down, have been transformed more and more into naked rocks, for with the woods with which they were clothed, the rains which formerly irrigated the earth have also disappeared or diminished.' From a similar cause, says Boussaingault, the sources were all dried up in the neighbourhood of a rapidly growing settlement in South America. But the long civil wars which followed after the separation of the colonies from Spain, drove away the settlers. Forests once more took possession of the ground, and since that time the sources have again begun to flow in consequence of the more frequent rains.

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[1] 'Zeitschrift für allgemeine Erdkundo,' Bd. II. Heft i.

The air is not only enlivened by the voices of countless animals ; the plants also form, as it were, a grand orchestra, which accompanies all the movements of the atmosphere with sounds responsive to its various humours. The gentle rustling of the leaves harmonises with the mild vernal breeze which blows softly through the grove ; and when the storm raves among the lofty crowns of the large forest-trees, their deep hollow notes are fit companions of the loud uproar of the elements.

The sounds proceeding from a forest have at all times found an echo in the breast of man. When the leaves rustled in the sacred groves of Mona, our forefathers fancied they heard the voice of a present deity. But as in untutored minds pious feelings too often degenerate into superstition, the mighty sounds which the storm elicits from the woods have filled many a lonely wanderer with terror. When the tempest sweeps over the Hartz Mountains, the wild huntsman raves with his hellish pack over the creaking trees, the howling of evil spirits is distinctly heard, and these imaginary spectres cause the bravest forester to tremble.

CHAPTER XXIX.

THE AERIAL LIFE OF INSECTS.

Admirable Formation of Insects for an Aerial Life--The Butterfly an Emblem of Immortality—The Ichneumon Flies—Aerial Concerts of Bees—Short Aerial Life of the Ephemeræ—The Flights of the Dragon Fly—Locusts and Mosquitos—Luminous Flies.

ALL animals depend upon the oxygen of the air for their existence, but for many of them the atmosphere is more than a mere vast storehouse of the air they breathe—it is the busy scene of their activity, the light element in which they enjoy their life, or display their agility and prowess. As the fins of the fish enable it to cleave the water with rapid strokes, or as the terrestrial quadruped attached to the glebe roams over the fields or climbs the trees, thus these children of the air are formed by their wings and the light structure of their body for a free aerial life. But few of the mammalians enjoy the enviable faculty of detaching themselves

CICADA FRAXINI.
Skeleton of winged insect, to show adaptation for flight.

(The strong nervures are characteristic of this insect, which is very strong on wing.)

from the solid earth and flying through the atmosphere, while it has been awarded to the majority of birds, and to almost all the insects during the last stage of their changeful life.

First as caterpillars, with no other instinct than that of consuming an enormous quantity of food; then sinking as pupæ into a state of lethargy, they finally exchange their slow creeping motions or their somnolent condition for rapid evolutions in the air.

For this unfettered liberty of action in the light atmosphere they have been most admirably formed by Nature; every insect that buzzes about our ears is, in fact, a small organized aerostatic machine, which combines lightness and solidity in a much more perfect manner than the best constructed balloon. As a sponge imbibes water through a thousand pores, and distributes it in innumerable channels through its whole substance, thus the whole body of the insect is permeated by numerous air tubes, communicating with a series of spiracles or breathing pores, and not only branching out into numberless ramifications, so as to penetrate even the smallest and most delicate organs, but frequently also dilating into vesicles or sack-like expansions, the size of which is always in exact proportion to the powers of flight. Thus, by an admirable mechanism, the air-vessels which abundantly supply the insect with the oxygen needed for its active habits of life, diminish at the same time the specific gravity of its body, and enable it to support itself on the wing with less muscular exertion. The articulated abdomen, extremely moveable in those insects which maintain the longest and most powerful flight, serves as a rudder, like the tail in birds; and the wings are invariably situated near the centre of gravity, so that the weight they have to carry may be equally balanced, and their task rendered more easy. These organs, apparently so fragile and so weak, are frequently endowed with wonderful powers, so that the celerity of many insects comparatively to their size far surpasses that of the swiftest birds. It has been calculated that the wings of the common fly in its ordinary flight performs about six hundred strokes in a second, which impel it to a distance of five feet, a velocity which the insect can increase six or sevenfold when alarmed; and by instruments which enable us to tell with the utmost exactitude the number of vibrations due to any particular note, we learn that the shrill hum of the gnat results from its being able to execute many thousand flaps of its little wings in a second of time.

As in the fishes we not only admire the perfect adaptation of their structure to their wants, but view with delight the metallic lustre of their scales, thus also many insects are invested with the most brilliant colours; and as the former add new charms to the submarine thickets in which they disport themselves, so also the insects fluttering from flower to flower, or hovering in the forest glades, may well be called the wandering gems of the aerial world. Splendid before all others are the butterflies—the friends of warmth and light, the lively companions of a bright summer's day. Clothed in silk, invested with purple, decorated with all the colours of the rainbow, and gay as the brilliant morn, the luminous rays of the sun appear to be the very principle of their being, for in a clouded or a chilly atmosphere their energies become suspended, and, folding their lustrous wings, they repose like sickly beings upon some drooping flower. Their mode of life corresponds with their beauty; disdaining all grosser food, they sip the nectareous juices which are distilled from flowers, or suck the saccharine substance which exudes from the leaves of vegetables. The labours of the indefatigable ant or of the industrious bee are alien to their habits—pure and uninterrupted enjoyment is the essence of their existence. Their wonderful metamorphoses have at all times attracted the admiration of all lovers of Nature. Other insects likewise undergo changes, but in none is so much magnificence evolved from such obscure beginnings, in none is the transformation so striking and so brilliant. On this subject, Swammerdam, a famous Dutch naturalist of the seventeenth century, finely remarks, 'In so wonderful a manner does the metamorphosis here proceed, that we see the resurrection painted before our eyes—that it lies, in fact, palpably before us. At first the caterpillar, creeping upon the earth, devours coarse food, and after having performed its functions for weeks and months in this low form, then passes into the intermediate stage of apparent death. Enveloped in a shroud, enclosed in a coffin, it generally lies buried under the earth. And now evoked by the sun the prisoner issues from his grave, casts off his coverings, and, attired in bridal vesture, enters into the enjoyment of a nobler condition—a condition in which all his faculties are developed in full perfection, in which, no longer bound to the earth, he wanders through the fields of air, sucks nectar from the cups of flowers, and begins to feel the delightful influence of love. Seeing all this, can we fail to notice a lively image of that happy futurity, when, at the call of the great sun of justice, the earth and the sea will give forth their dead, and the troops of the blessed live and love to all eternity?'

Thus, since the remotest times, the butterfly has been considered as the symbol of immortality, and it was not without reason that the Greeks gave the same name—Psyche—to the beautifully-adorned insect and to the soul. But the Greeks were not the only nation of antiquity that found in the butterfly the image of a spiritual existence after death, for long before the Chinese and Egyptians used it as a symbol in their sepulchral monuments and sarcophagi, showing at the same time how deeply the idea of immortality is rooted in the human mind.

Despite their beauty, the butterflies, in consequence of the ravages their innumerable legions commit while in the caterpillar state, are enemies more formidable to man than the most ravenous beasts of prey; and probably they would have rendered agriculture utterly impossible if the winged and equally innumerable hosts of the ichneumon flies did not hold them in check, and keep their multiplication within bounds.

Some of these useful insects deposit their eggs upon their chosen victims; others insert them by means of a sharp and strong abdominal tube or ovipositor into the bodies of the caterpillars, where they are hatched in a few days, and subsist on the juices of their victim, which, though mortally wounded, may continue to exist for some time, thus affording them a continued supply of nutriment.

When we read that more than six thousand species of butterflies exist in Europe alone, we may feel alarmed for the produce of our fields and gardens, but their arch-enemies the ichneumonides are no less numerous, and by the destruction of countless myriads of larvæ, which would otherwise be left to banquet on the fruits of the earth, are of the most essential service to mankind.

In spite of their vast numbers, the ichneumons form but a small part of the order of the hymenopterous insects, which contains besides the countless hosts of the wasps, bees, and ants. Less beautiful than the butterflies, and far less formed to attract the eye, their wonderful instincts render them far more interesting. Who is ignorant of the admirable polity of the honey bee, the neatness and precision with which it constructs its cells, and the diligence with which it provides during the warmth of summer for the support of the hive during the rigours of the succeeding winter? It is a pleasing sight to watch the industrious little creatures buzzing over a flower-bed, or diving into some broad-mouthed corolla; and at the time when a clump of tall linden trees is filling the air with fragrance, the ear is at the same time gratified with the hum of countless bees, who, attracted by the delicious perfume of their savoury banquet, form an aerial concert alternately swelling and subsiding like the hollow murmur of a distant multitude.

The name of ephemeræ, or day-flies, shows that but a very short time has been allotted to the insects thus called, for their aerial gambols. Some of them live but a single hour, very few prolong their career during a whole summer's night, most of them only begin their flight after sunset, and die without having seen the light of day. What a world of wonder thus lies beyond the reach of their sensations; and supposing they had reason, how limited would be their ideas of the universe! And who can tell the infinity of things beyond the experience and intellect of man, who, in spite of his great pretensions, is after all no more than an ephemera with a wider range of vision?

For the shortness of their winged life, the ephemeræ are compensated by the long duration of their larval state, which lasts two or three years, and is passed, like that of the gnats, in the water. When the change of a subaqueous for an aerial life is about to take place, the larva rises at eve to the surface of the lake or river, and, divesting itself of its skin, prepares to launch forth into another element. Its numbers are sometimes so immense that the whole surface of the water appears to become suddenly instinct with life, and to dissolve itself into an innumerable winged army, which soon fills the air, thick as a fall of snow, or as the pitchy cloud

> Of locusts warping on the eastern wind
> That o'er the realm of impious Pharaoh hung
> Like night, and darken'd all the land of Nile.

A swarm of day-flies circling round a street lantern affords a very lively and beautiful spectacle. They fly in such close array, and the fine texture of their gossamer wings has so brilliant a lustre, that it seems as if bands of silver were constantly wheeling in all possible directions round the light. They frequently in these circling evolutions strike against each other and fall down; but new swarms constantly pour in to trace the mazy round, until long before midnight the animated cloud disperses, and but a few stragglers remain. Next morning the ground about the lantern is found covered many inches deep with their dead bodies, and bears witness to their amazing numbers.

The ephemeræ which rise out of the water before twilight likewise afford a magnificent aerial spectacle, when on a fine evening their countless myriads, attired in silver, and gilded by the setting sun, rock themselves to and fro in the balmy atmosphere.

Like the short-lived ephemeræ, the dragon-flies, to whom a longer aerial existence has been given, belong to the order of the neuropterous insects. Like them also they were at one time inhabitants of the water, and resided in that element for a long period before they began their aerial life.

The wings of these lively and elegant insects, though not so gaudily coloured as those of the butterfly, are of a beautiful transparency, and reflect all the tints of the rainbow as they dart with the velocity of a hawk through the forest glade, over hedges or over the bushes on the river banks. They make their appearance principally towards the decline of summer, and love to 'dedicate their beauty to the sun,' as it is chiefly on bright warm days that they are seen hovering about in quest of prey.

Though they generally make their appearance only in small numbers, they sometimes wander like the destructive locust in large cloud-like swarms. Their passage, however, is perfectly harmless, while the legions of the locust are the terror of the Orient, and as fatal as the most destructive flood or hailstorm to the fields on which they alight in their baneful progress. All human efforts to resist the invasion of these insect-clouds have proved fruitless. In the south of Russia, the locust-war, though carried on on a colossal scale, has been finally given up in despair. In the provinces subject to their periodical invasions, whole armies have been sent against them, and whole populations summoned to assist in their destruction, but the ukases of the mighty autocrat have often been of more avail in sweeping away nations than in extirpating the swarms of the locust. The firing of artillery and the conflagration of the steppe were found equally unavailing, and the power of a despotic government has been finally obliged to yield to more powerful Nature.

On crossing the Cordillera, Mr. Darwin once observed a ragged cloud of a reddish-brown colour. At first he thought that it was smoke from some great fire on the plains; but, a light breeze driving it towards him, he soon found that it was a swarm of locusts, of a species closely resembling the famous *Gryllus migratorius* of the East. The main body filled the air from a height of twenty feet to that, as it appeared, of two or three thousand above the ground, 'and the sound of their wings was as the sound of chariots of many horses running to battle, or, rather, like a strong breeze passing through the rigging of a ship. The sky, seen through the advanced guard, appeared like a mezzotinto engraving, but the main body was impervious to sight; they were not, however, so thick together, but that they could escape a stick waved backwards and forwards. When they alighted they were more numerous than the leaves in the field, and the surface became reddish instead of being green.'[1]

The order of the dipterous insects likewise contains a host of noxious and troublesome insects, which, though less destructive than the locust, hum and buzz about in the air, for the torment and annoyance of man. Gnats and mosquitos are the plague of every zone. They infest the banks of the Amazons or the Orinoco as well as those of the Lena or the Obi; their swarming multitudes accompany the heats of the short Siberian summer; and in the tropical lowlands, along the river banks or near lagunes, they hover above the water like a misty cloud. Our domestic fly, though not armed with a venomous sting, is also man's troublesome companion over a considerable part of the earth. An unwelcome guest, it makes its appearance in the Kaffir's craal and in the Laplander's tent, and is equally at home in the West Indies and in England, where it visits both the mansions of the wealthy and the cottages of the poor.

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[1] 'Journal of Researches, chap. xiv.

Among the insects which people the air during the day the beetles play but an inconsiderable part; but some of them afford a splendid spectacle by night, when their glittering squadrons, floating in the atmospheric ocean, emulate the seas gleaming with phosphoric light. Appearing but sparingly and with inconsiderable effect in northern lands, the numbers and the brilliancy of the luminous beetles increase on approaching the equator. In Italy, the lucciola (*Lampyris italica*), darting a vivid ray with every stroke of its tiny wings, deserves the poetical name of 'flying star,' given to it by Pliny; and the glowing elaters of the tropics not seldom blaze like a firework on the river banks.

CHAPTER XXX.

AERIAL BIRD-LIFE—BATS—FLYING FISHES.

Birds the Enliveners of the Atmosphere—The Albatross—The Frigate-Bird—The Tropic-Birds—The Stormy Petrel—The Lämmergeier—Matthisson and the Golden Eagle—The Condor—The Oricou—The Humming-Birds—The Songsters of the Grove—The Migrations of Birds—Adaptation of Birds for Flight—Their Aerial Conflicts—Bats—Flying Fishes.

IN spite of its majestic motions, its never-resting tides and surging waves, the ocean would still be a mere desolate waste, a melancholy desert, if the countless animals which people its wide domains did not gladden the eye of the beholder with ever-changing scenes of life.

And thus also the aerial regions would seem but a vast and dreary solitude, if a multitude of winged beings, crossing them in every direction, even as the fishes animate the waters, did not enliven them with a perpetual succession of entertaining pictures.

Among the creatures to whom the air has been assigned as the theatre of their activity, the insects indeed form the majority; but the birds are the most conspicuous and interesting by their larger size, their superior organisation, the beauty of their plumage, or the sweetness of their song. The butterfly, indeed, has a garb as splendid as that of the humming-bird, but it has nothing else to boast of, or to render it worthy of attention; while not a bird cleaves the air that is not possessed of some admirable instinct, or some glimpse of intelligence, that makes it interesting or endears it to man. The flight of the insects is, moreover, confined to the lower strata of the atmosphere; they seldom rise to any considerable height above the surface of the ground, while the birds range over a far wider expanse, soar over the highest mountains, and still call the atmosphere their home where man would be unable to breathe.

At all times of the day, in all seasons, in every clime, these active denizens of the aerial regions animate and adorn them by their presence. The early morn would be deprived of half its charms, if a merry chorus of birds did not hail it with its pleasant voices; and the soft evening hour seems far less sweet without the nightingale's melodious note.

Wherever the traveller may wander—in the arctic wastes, or among the snow-fields of the high mountains; on dreary uninhabited coasts, or on the open sea—everywhere he finds these desert regions enlivened by birds; everywhere he greets them as the welcome companions of his solitary path.

In the gloomy wildernesses of Iceland, where no hut announces the presence of man, and no herd is seen to roam over the dark and sterile lava-grounds which cover so large a space of that picturesque but desolate country, he doubly rejoices at the sight of the magnificent wild swan, both on account of its snow-white plumage, and of its loud shrill voice, which, when resounding high in the air, strikes the ear like the distant clang of a trumpet. Inharmonious in itself, it has a peculiar charm in these unfrequented wastes, where it alone interrupts the death-like silence which reigns around.

Whoever has sojourned on a solitary coast where grey sand dunes extend for miles, or where the surf beats against precipitous cliffs, cannot fail to have watched with interest the sea-gulls' flight, as with easy grace they glide over the surface of the water, or wheel about in the air with outstretched pinions, their white plumage gleaming in the sunshine, or contrasting with the dun clouds and dull grey water. In these wild solitudes it is pleasant to hear their cry mingling with the hoarse rolling of the surge and the moaning wind.

Along the gloomy shores of the north many a naked cliff or rocky islet rises from the bosom of the sea. Beaten by the tempest, exposed to the never-ceasing attacks of the surging wave, it would be the absolute picture of desolation if countless sea-birds had not chosen it for their place of rest. Through their presence a scene which would otherwise have been the image of death becomes a spectacle of abounding life. On spots like these, where the girding sea secures them from the attacks of all four-footed beasts of prey, though not from the rapacity of man, they breed and nestle in such prodigious numbers that they may be said, without exaggeration, to deafen the ear when they scream, and to darken the sun when they fly. When disturbed in their rest by the fowler's gun, the dreadful alarm spreads from cliff to cliff, and

> Thick as autumnal leaves that strow the brooks
> In Valombrosa,

their screeching legions rise into the air. The flapping of their wings and their loud discordant cries raise a tumult like that of a vast congregated multitude, and deceive the lonely wanderer with the false clamour of a populous city.

Not only along the shores of the ocean, but on the high seas also, where day after day the monotonous spectacle of an interminable waste of waters wearies the eye, the flight of birds becomes a source of amusement to the traveller, and beguiles his tedious hours.

In the southern Pacific the lordly albatross is foremost in attracting his notice, as, heedless of the gale, the noble bird glides along in his own native element, and, without ever touching the water with his pinions, rises with the rising billow and falls with the falling wave.

While the albatross rarely approaches the verge of the equatorial seas, the frigate-bird hovers over the tropical waters. Its singularly easy and graceful flight affords all the charm of variety. Sometimes it is seen balanced in mid-air, its wings spread but apparently motionless, its long forked tail expanding and closing with a quick alternate motion, and its head turned inquisitively downwards; sometimes it wheels rapidly, and darts to the surface of the water in pursuit of prey, and then again it soars so as to be lost to vision. Such are its prodigious powers of flight, that though frequently seen hundreds of miles from the nearest land, it returns every night to its solitary roost. The impatient mariner who, weary of ploughing day after day the desert of waters, sees the frigate-bird soaring amidst the clouds at an immeasurable height, may well sigh for the possession of pinions which would so soon transport him to the port he longs to reach, and to which he is so slowly wafted by the inconstant winds.

While the fishermen are pursuing their vocation on some solitary shore, the frigate-bird may often be seen taking its aerial stand over their heads, and noticing their motions with exemplary patience. Pelicans, gulls, and other sea-birds, are also found watching with equal eagerness the issue of the fishermen's progress, attracted to the spot by the sea of living objects immediately beneath them. And there it is, when these men are making their last haul, and the finny tribe are fluttering and panting for life, that the frigate-bird starts into sudden activity. His hungry competitors have scarcely secured their prey by the side of the fishermen's canoes, when they are pounced upon with such violence that to escape its rapacious assaults they readily in turn abandon their hard-earned booty to this formidable opponent.

Similar scenes of dramatic interest, where the weaker robber is obliged to yield to the stronger, are of frequent occurrence on the confines of air and ocean. Incapable of diving or plunging, their feathers being too large in proportion to their bulk, the larger raptorial gulls live by the exertions of the lesser species, compelling them to drop or disgorge the prey they have just picked out of the sea, and dexterously catching the ejected fish before it reaches the water. Thus, among the winged denizens of the air, as among the finny tribes or the creatures attached to the soil, we always find the right of the stronger asserting its brutal power.

Along with the frigate-bird, the phaëtons or tropic-birds contribute to the amusement of the traveller as he crosses the equatorial seas. Nothing can be more graceful than the flight of these elegant creatures. They glide along most frequently without any motion of the wing on the sustaining air, but at times this smooth progression is interrupted by sudden jerks. When they perceive a ship they never fail to sail round it, as if to reconnoitre. Though disporting in the air far at sea, their extraordinary length of wing enables them, like the frigate-birds, to return every evening to the lonely rocks where they place their nests.

The stormy petrel accompanies the seafarer in every zone. Diving or swimming with perfect ease over the surface of the most tempestuous sea, it yet seems to foresee and fear the coming storm before the seaman can discover any appearance of its approach—flocking together and uttering piercing cries, as if to warn the mariner of his danger. On account of its dark plumage and its frequent appearance before the storm, it is considered as a bird of ill-omen by the ignorant seaman; but the traveller who does not share the vulgar superstition delights to see it whisking with the celerity of an arrow through the deep valleys of the abyss, and darting away over the foaming crest of some mountain wave. The small size of the bird, which is not more than six inches in length, and its apparent weakness, form a strange contrast with the turbulent scenes in which it loves to disport itself. Had the ancients been as well acquainted with the wide ocean as the mariners of modern times, they would no doubt have made the stormy petrel the subject of some graceful fable.

On turning our view from the sea to the high places of the earth, we here also hail the appearance of birds as the enliveners of the atmosphere. Bathed in the purest air, nearest to the sun of all the feathered tribes, the great eagles and vultures look down upon the mountain wildernesses as the lords of all they survey.

After a long and toilsome march, attended with many a danger, the Alpine tourist has at length reached the summit of a peak clothed, even in the depth of summer, with eternal snow, and enjoys, as the well-earned reward of his laborious ascent, the magnificent mountain scenery inclosed within his immense horizon. He fancies himself alone in this sublime wilderness, for far below he left the last traces of life. But suddenly, high over his head, he hears a long-sustained, clear piping tone; he looks upward, and, emerging from the dark blue firmament, a black spot advances nearer and nearer towards him, and, growing as it approaches, at length wheels round him with wide, outspread wings. It is the mighty lämmergeier, the monarch of the High Alps, who, casting an inquisitive glance upon the stranger, seems to ask him how he dares to 'disturb his ancient, solitary reign.' But soon, as if in mockery of the slow-paced intruder, the imperial bird glides away through the thin air, and scarce have a few minutes elapsed when his piercing cry is heard over the rocky crest of some far-distant mountain.

LÄMMERGEIER.

At early dawn the lämmergeier leaves his nest, and, hovering in the clouds, sweeps with his incredibly sharp eye over the Alpine precipices and deep valleys far below. Suddenly folding his wings, he drops down like a thunderbolt upon the unsuspecting lamb or mountain hare he has espied from his lofty station, and which, before it can think of flight, is already hopelessly lost, and triumphantly borne aloft by its exulting enemy.

When pressed by hunger the lordly bird wages many a fierce battle with animals too heavy or too strong to be carried away in his talons. On seeing an old chamois grazing on the brink of a precipice it wheels in narrowing circles over the ill-fated creature, terrifies and stuns it by repeated blows of its mighty wings, and not seldom causes it to fall headlong into the abyss, where it feasts upon the shattered carcase, or tears it to pieces to provide for its hungry young.

Even the solitary hunter, watching for game upon some narrow ledge, is not secure from its bold attacks, and, while meditating the chamois' death, finds himself obliged to defend his own life against the undaunted lämmergeier. Such as have luckily withstood the impetuous assault of these ferocious birds, or the equally formidable golden eagle, affirm that the deafening noise, the rapidity and strength of their enormous wings, produced a completely stunning effect upon them.

Christian Danuser, of Felsberg, forester in Val Misocco (Canton of the Grisons), stood one morning, about the middle of October 1856, near the edge of a high rock wall, on the look-out for chamois. Alarmed by a strong and rapidly-increasing noise in the air, he looked up, and saw, about sixty feet over his head, a golden eagle on the point of swooping upon him. Danuser, well acquainted with the bird's perfidious mode of attack, sprang rapidly backwards, and had scarcely time to throw himself flat down upon the ground, when the eagle pounced upon the spot where he had stood, grazing him with the tip of one of its wings. As soon as the bird in its impetuous descent had missed its intended prey, Danuser suddenly sprang up, and, levelling his gun at the slowly reascending eagle, shot it at the moment it was preparing for a renewed attack.

While in this and similar cases the great birds of prey appear as the enemies of man, Matthisson[1] was once indebted for his life to the flight of a golden eagle. The poet, in one of his Alpine excursions, had lost his way in a desolate mountain wilderness, from which it seemed hopeless to find an issue. Completely exhausted, he consumed the small portion of bread and wine he carried with him, convinced that he had taken his last repast, and, reclining upon the rock which had served him as a table, soon fell asleep. His life now hung upon a very slender thread. In his exhausted condition the continuance of his sleep till after sunset was more than probable, and in this case he would have been the certain victim of the night's frost. To expect any succour from man was as vain as in the wildernesses of an uninhabited island. In this crisis of his fate, a bird of prey, flying past so near and with a shriek so loud as to awaken him from his death-like slumber, was destined to become the means of restoring him to his friends and human society. To judge by the voice, which, though far distant, still had a piercing sound, it must have been a golden eagle, though the poet could not exactly distinguish the species, for before he fully awoke from his somnolent condition the tutelary bird was already nearly lost to sight.

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[1] 'Erinnerungen.'

Strengthened by his slumbers, the discovery of a path leading out of the wilderness was now attempted with better success. Following the bed of a mountain torrent, Matthisson at length heard the near sound of bells (which are generally attached to the necks of the cattle in Switzerland), accompanied by the song of the herdsmen; and never did a sweeter music greet his ear than these rude notes, which gave him the assurance that he was about to re-enter the land of the living.

More powerful, and provided with a greater expanse of wing than the lämmergeier, is the gigantic vulture of the Cordilleras—the condor, the largest of all flying birds. The lämmergeier always remains within 15,000 feet above the level of the sea, but the condor is often seen hovering high above the Andes. At daybreak, while deep night still rests upon the earth below, he sees the sun rise over the distant primeval forests of Brazil; in the evening, long after the highest snow-peak has disappeared in darkness, he still sees its fiery orb resting on the border of the far-distant Pacific. Spread out beneath him is all the magnificence of Nature—mountains, valleys, rivers, forests, the sea; now his eye glances over the eternal winter of the glaciers, and then over palm-trees and bananas. And not only does his vision embrace a wider horizon than that of any other created being, he is also able to swoop with incredible swiftness from an immeasurable height down to the level of the sea.

One moment he hears the shrill pipe of a vicuña in a high mountain valley of the Andes, and the next the barking of a seal mixing with the hollow roar of the breakers on the coast; scarce has he faced the sharp wind of the puna, blowing over icy wildernesses, than he glides over a shore heated by a tropical sun. Thus in a few minutes he flies through all climates, and breathes with equal facility under an aerial pressure of 28 inches and of 12. In altitudes where blood flows from the lips and finger-ends of man, who can hardly move a few paces with the greatest exertion, the condor glides with majestic ease through the rarefied air.

But it is not only the flight of the great raptorial birds, and the graceful ease with which they rise and fall in the rarefied atmosphere, that renders their aerial journeyings so interesting. The keenness of vision, which enables them to watch, from their lofty position in the clouds, all that is passing at a vast distance below, is no less worthy of admiration.

From an altitude where the great African oricou, or sociable vulture, though measuring above ten feet with expanded wings, appears to human vision but as a small black speck in the dark blue sky, the restless eye of the hungry bird sweeps over the immense horizon below it, and has soon discovered a prey. For already the smaller rapacious birds—crows and dirty carrion vultures (the rabble of the race)—have assembled round some fallen animal, and attract by their movements the attention of the monarch of the air. Descending to a lower level, a glance suffices to give him a clear perception of what is going on. He sees at once that a plentiful repast awaits him, and, folding his pinions, he shoots down with the rapidity of a meteor. But before he reaches the earth he again unfolds his wings, and, stretching out his feet, alights leisurely upon his prey, while the inferior birds, scared by his approach, keep at a respectful distance, and wait for the pickings he may leave them.

As the raptorial gulls live by the exertions of the lesser sea-fowl, thus also the great sea-eagles frequently force their weaker relatives to give up to them the fish they have caught, and establish, as it were, the old feudal relations of baron and serf in the aerial domains.

One of these scenes is vividly described by Wilson, the American ornithologist:—'Elevated upon a high dead limb of some gigantic tree that commands a wide view of the neighbouring shore and ocean, the white-headed sea-eagle seems calmly to contemplate the motions of the various feathered tribes that pursue their busy avocations below—the snow-white gulls slowly winnowing the air; the busy *tringae* coursing along the sands; trains of ducks, streaming over the surface silent and watchful; cranes, silent and wading; clamorous crows, and all the winged multitudes that subsist by the bounty of this vast liquid magazine of Nature. High over all these hovers one whose action instantly arrests all the eagle's attention. He knows him to be the fish-hawk, settling over some devoted victim of the deep. His eye kindles at the sight, and, balancing himself with half-opened wings on the branch, he watches the result. Down, rapid as an arrow from heaven, descends the distant object of his attention, the roar of its wings reaching the ear as it disappears in the deep, making the surges foam around. At this moment the eager looks of the eagle are all ardour, and, levelling his neck for flight, he sees the fish-hawk once more emerging, struggling with his prey, and mounting in the air with screams of exultation. These are a signal for our hero, who, launching into the air, instantly gives chase, and soon gains on the fish-hawk, each exerting his utmost to mount above the other, and displaying in the rencontre the most elegant and sublime aerial evolutions. The unencumbered eagle rapidly advances, and is just on the point of reaching his opponent, when, with a sudden scream, probably of despair and honest execration, the latter drops his fish. The eagle, poising himself for a moment, as if to take a more certain aim, descends like a whirlwind, snatches it in his grasp ere it reaches the water, and bears it silently away to the woods.'

Even a brief description of the numerous birds that enliven the forests and the fields would fill a volume of many chapters. In every zone, in every country, new species make their appearance, and everywhere delight the eye or enchant the ear. As the fishes—the birds of the sea—move in glittering squadrons through their denser element, thus also the birds—the winged fishes of the aerial ocean—are decorated with all the beauties of colour.

In tropical America the lustrous humming-birds attract the wondering gaze both by the metallic brilliancy of their plumage and the incredible swiftness of their flight. With lightning speed these gems of the air dart from flower to flower, now hovering for an instant before you, as if wishing you to admire their surpassing beauty, and now again vanishing with the rapidity of thought.

Fully confiding in its prodigious celerity of flight, the humming-bird will approach you within a few inches; but, however anxious you may be to catch it, it darts away like an arrow before you can raise your hand, and mocks your vain attempt.

On turning our view to the old world, to the fortunate islands of the Indian Ocean, we find the glittering humming-birds replaced by the no less splendid troop of the sun-birds, or cinnyridæ. Like them they thrust their slender beaks into the deep-cupped flowers, to probe them with their brush-like tongues for insects and nectar. Like sparkling emeralds and rubies, they swiftly glide from shrub to shrub—a charming existence, which revels in a perpetual spring, and knows neither the rough autumnal blast nor the cold breath of winter.

Not only by their rapid evolutions and the beauty of their plumage do the birds enliven the air—their various notes also impart, as it were, a soul to the atmosphere, and lend a voice to inanimate Nature. Their charming concerts are not confined to a few favoured climes. They resound through every zone, and everywhere proclaim, in a thousand different strains, the pleasant season when the woods clothe themselves with fresh verdure, and Flora awakens from her trance.

Who, at the return of spring, does not rejoice at the numberless songsters of the groves and fields, at the nightingale's soft lay, or at the bonnie skylark, 'upward springing blythe to greet the purpling east?' Or who, when the cuckoo's reiterated note bursts upon him from the deep silence of the woods, would not exclaim with Logan—

Hail, beauteous stranger of the grove!
  Thou messenger of spring!
Now Heaven repairs thy rural seat,
  And woods thy welcome sing.

What time the daisy decks the green,
  Thy certain voice we hear;
Hast thou a star to guide thy path,
  Or mark the rolling year?

Delightful visitant! with thee
  I hail the time of flowers,
And hear the sound of music sweet
  From birds among the bowers.

Far to the north the snow-bunting enlivens even the treeless barren grounds with his melodious note, and the solitary pine-forests of the polar regions welcome the lengthening days with aerial symphonies. 'Within the arctic circle,' says Sir John Richardson, 'the woods are silent in the bright light of noonday; but towards midnight, when the sun travels near the horizon, and the shades of the forest are lengthened, the concert commences, and continues till six or seven in the morning. The transition is so sudden from the perfect repose, the death-like silence, of an arctic winter, to the animated bustle of summer (the trees spread their foliage with such magical rapidity, and every succeeding morning opens with such agreeable accessions of feathered songsters to swell the chorus—their plumage as gay and unimpaired as when they enlivened the deep green forests of tropical climes), that the return of a northern spring excites in the mind a deep feeling of the beauties of the season, a sense of the bounty and the providence of the Supreme Being, which is cheaply purchased by the tedium of nine months of winter. The most verdant lawns and cultivated glades of Europe, the most beautiful productions of art, fail in producing that exhilaration and joyous buoyancy of mind which we have experienced in treading the wilds of Arctic America when their snowy covering has been just replaced by an infant, but vigorous vegetation. It is impossible for the traveller to refrain at such moments from joining his aspirations to the song which every creature around is pouring forth to the great Creator.'

Man wanders with difficulty from his native soil, but the path of the more fortunate bird of passage is through the free regions of air. What to us would be a long and fatiguing journey is to this light-winged traveller but a short pleasure excursion to other scenes.

BIRDS OF PASSAGE.

Before the want of food makes itself felt, before the arrival of the wintry blasts, we see the migratory bird wing his flight towards the meridian sun. Neither hunger nor cold can thus be the only motive which prompts his wanderings; for, if this were the case, the migratory instinct would only awaken in cold countries, and cease in regions where winter is unknown. We then should not find, under the twelfth degree of northern latitude, the same restless, travelling instinct still leading our swallow to an unknown bourn. In Egypt she has both food and warmth; but neither here nor in Nubia does she tarry during the winter, but flies away still farther south, to lands which no European traveller has ever seen.

Our stork also, who surely would not want for worms and reptiles in the swamps of the country of the Pharaohs, mostly chooses the equatorial lands for his hibernal residence, and, together with our nightingale—her Egyptian representative—the Sylvia galactodes, wings her way towards the equator. The pelican also, a native of the Nilotic plains, feels the same restlessness at the approach of winter, and migrates into the interior of Africa.

Why do these birds wander whom no apparent want drives to such immense distances from their native haunts? And who guides them back again to the land of their birth, although their journeys are frequently made during the night, high in the air, over seas and mountain chains, and in different seasons, when the lands they traverse wear a very different aspect? Truly this migratory instinct is one of the great mysteries of Nature!

BIRD COLONY IN HOLLAND.
(From a sketch made on the spot.)

The wanderings of birds have at all times attracted the notice of man, and tuned his mind to sadness or to joy.

Every child feels happy when the songsters of the grove return to their summer haunts; and when the first stork makes its appearance in the Dutch lowlands, it awakens pleasant sensations of spring, and verdure, and sunshine in every breast. How different in autumn, when the aerial travellers wing their flight to more sunny lands, leaving us to the keen blasts of winter howling in the leafless woods! In his 'Ode to the Cuckoo,' Logan has given a fine expression to the soft melancholy which their departure inspires:—

Sweet bird! thy bower is ever green,
Thy sky is ever clear,
Thou hast no sorrow in thy song,
No winter in thy year.

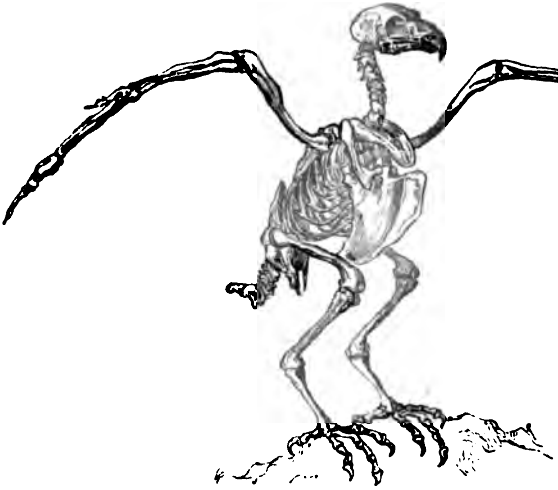
Oh! could I fly, I'd fly with thee,
We'd make with joyful wing
Our annual visit o'er the globe,
Companions of the Spring.

A glimpse at the organisation of the volatile birds shows us how admirably they are fitted for their aerial life. The breast-bone is enormously developed both in length and breadth, and provided, moreover, with a keel, which serves as a point of attachment for the muscular masses which set the wings in motion.

To assist the action of these organs of flight they are provided with a crest of quill feathers, more or less elongated, and decked with coverts imbricating over each other like the tiles of a roof. When expanded, these feathers press like a light fan upon the elastic air-wave beneath; and not only do they enable the bird to sustain her flight with less exertion, but they are, moreover, an excellent waterproof mantle, and, being bad conductors of heat, allow their possessor to bear more easily the frequent variations of temperature to which his aerial life exposes him.

Besides the expansive wings, the small head, the pointed beak, the long and pliant neck, the gently-swelling shoulders and the tapering tail (acting like the rudder of a ship and enabling the bird to rise or fall or remain in a horizontal position), all combine to assist and accelerate motion through the yielding air.

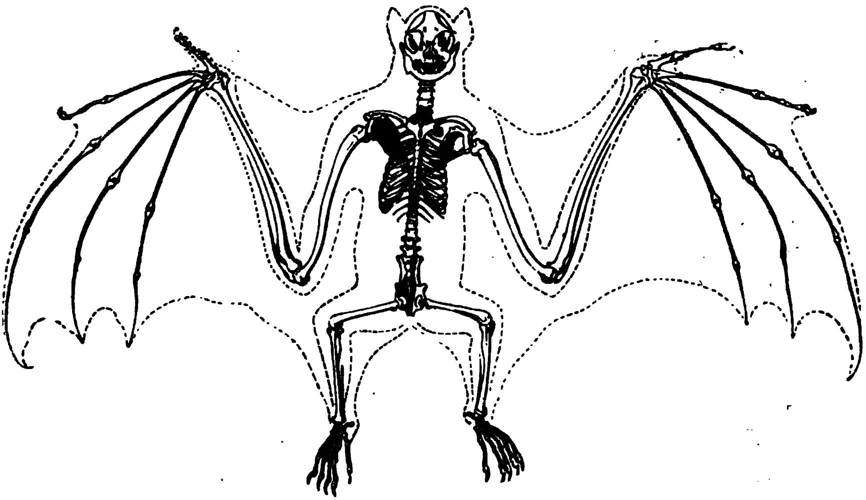
The internal structure of birds is no less admirably adapted to the same purpose. The vital air penetrates every part of the interior of their bodies. It passes through and round about the lungs, bathes the surfaces of the viscera, enters the cavities of the bones; and even finds its way into some spaces between the muscles of the neck. This not only secures the most perfect oxygenation of the blood, but, the temperature of the blood being very high, the air in every part is rarefied, and contributes to the specific lightness of the bird. The muscles, except those which serve to move the wings, are extremely delicate; the bones thin and generally hollow. To diminish still more the specific gravity of the body, a number of sacks or cells distributed over the cavities of the breast and abdomen, and communicating with the lungs or the wind-pipe, can be voluntarily distended with air, like the bladder which enables the fishes to rise in their native element.



SKELETON OF BIRD.

Thus beautifully constructed for swimming in the aerial ocean, the bird surpasses by far the swiftest of the finny tribes in the rapidity of its movements, since the lighter element in which he lives opposes less resistance to his exertions.

As the wide seas are the theatre of constant wars, of a perpetual pursuit and flight, of a constant alternation between victory and death, so also in the atmospherical ocean we see one winged creature devour another, and become in its turn the prey of superior strength. The sweet songsters of the grove, the delight of man, are terrible enemies to the insects, whom they sweep away in countless millions; and they again are torn to pieces and devoured by the lanner or the hawk. The large migratory swans and geese that wing their flight to distant regions, are not exempt from the lot of the smaller birds, for the powerful eagles and falcons are waiting for their passage to carry them off in their mighty talons; and even these tyrants of the air must yield to the arch-tyrant and destroyer—man.



SKELETON OF BAT.

The solid earth is the quadrupeds' chief domain—the field where they seek their food and enjoy their sports; but as some fishes wander about on land or climb upon trees, and some birds unable to fly spend most of their time in the water, thus, as exceptions from the general rule, some of the mammalia have the seas for their home, while others pass their whole active life in the air, where they seize their prey on the wing, or vault or fly from one tree to another. The earth serves them merely as a resting-place; otherwise they are constantly chasing or disporting themselves in the atmosphere.

The far-spread family of the bats has been as beautifully formed for this aerial existence as the light-winged birds. On examining their skeleton we are at once struck by the enormous development of the bones of the forearm and fingers. Like the frame of an umbrella, they serve for the expansion of a thin membrane which reaches also to the hind legs, and from them to the tail, and renders them the same services as the wings of the feathered tribe. While resting on the earth the movements of the bats, impeded, as it were, by the folds of a wide mantle, are, of course, exceedingly awkward, but in their own element they fly about with graceful ease.

Scattered over the earth in a great variety of genera and species, these singular animals are particularly numerous in the torrid zone, where they also attain the largest size. Some of them live on juicy fruits; but the greater part are insectivorous, and commit the same ravages among their tiny victims as the pike in the waters of a pond or the falcon among the smaller birds. By day they conceal themselves in dark caves, hollow trees, or ruined buildings, where they rest in drowsy clusters suspended by their hinder claws; but when the sun sinks below the horizon they awaken to activity, and launch forth into the air like vessels quitting the port with swelling sails.

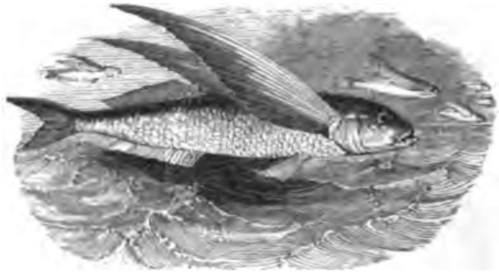
Then they may be seen hovering about in the dim evening, or by the light of the moon in the forest glades, or over the rivers and ponds, busily engaged in the pursuit of the crepuscular or nocturnal moths, and other insects which, torpid like themselves during the day, prefer obscurity and darkness to the glittering sunbeam.

Thus they impart life and animation to the nocturnal atmosphere; but this life, this silent gliding through the realms of night, has a gloomy character in unison with the surrounding scene. The twittering sparrow and melodious lark are ever welcome to us as the delightful harbingers of spring, as the lively companions of bright hours and sunny fields; but the sombre bat inspires sentiments of a sad and melancholy nature, and is made to figure in many a superstitious tale—for man, who has been born for the enjoyment of daylight, has an instinctive aversion to all creatures that delight in obscurity.

BATS HOVERING OVER RIVER BY MOONLIGHT.

A far more pleasing spectacle is afforded by the flying fishes of the warmer seas, whose silvery wings and blue bodies, reflecting the light of a tropical sun, sparkle like a shower of brilliants when, as is frequently the case, these birds of the ocean are seen rising from the water by thousands at once, and darting about in all possible directions. For this faculty of sustaining themselves for a time in the air, the flying fishes are indebted to their pectoral fins, which are so considerably developed beyond the ordinary measure, that when they leap out of the water to escape the persecution of their enemies, they are able to fly to a considerable distance, and so high as frequently to fall upon the decks of ships. While swimming, they are not impeded by their wing-like fins, which fold together close to the body; and thus these singular creatures are able both to cleave the water with all the celerity of ordinary fishes, and to wing their flight to some distance in an element not their own. The advantage thus afforded them in escaping from the pursuit of the dolphins and bonitos is, however, but apparent, for while seeking their safety in the air they often fall a prey to the gulls and frigate-birds, who pounce upon them with lightning-like rapidity before they fall back again into the water.

The mariner, tired by the monotony of a long sea-voyage, finds a great source of entertainment in following the lively evolutions of the rapacious sea-birds scattering the flying fishes about in silvery showers, or in watching the rapid chase of the dolphin, who, swift as an arrow, pursues the feeble aeronaut, keeping him steadily in view and ready to seize him at the moment of his descent. But the flying fish often eludes the bite of this vigilant enemy, for—even as Antaeus rose with new-born vigour as soon as Hercules cast him down upon his mother earth—he gains new strength as he touches the water, and, instantaneously renewing his prodigious leap, not unfrequently baffles pursuit by his extreme agility.



FLYING FISH.

CHAPTER XXXI.

INFLUENCE OF CLIMATE ON THE HEALTH AND CHARACTER OF MAN.

The Box of Pandora—Dust—The Germs of Disease Floating in the Atmosphere—Malaria—The Air of Towns—Effects of a Change of Climate—Sea and Mountain Air in Climates Suitable for Consumptive Patients—Madeira—Egypt—Bracing Climates—Beneficial Effects of Travel on Health.

THE fabulous box of Pandora contained, as we are told, all the diseases to which poor humanity is subject. When it was opened by its too curious possessor, they all flew out at once, nor has all the physician's skill been able to confine them again in their ancient prison. They still are hovering by thousands in the atmosphere, ever ready to seize the first opportunity for making some insidious attack upon our health. The air we breathe, the first necessary of our life, the carrier of health and longevity, is, at the same time, the inexhaustible arsenal where Death forges his weapons for our destruction. Every change of temperature and moisture, every rise and fall of the barometer, every wind that blows, is pregnant with disease. A sharp frost at once increases the mortality of our cities and carries away many a consumptive patient who, under the influence of a mild temperature, might have witnessed the return of spring; and, on the other hand, the prolonged heat of summer occasions its own peculiar maladies, and envenoms many a complaint that might otherwise have spared its victim.

But not only by the perpetual changes which take place in the physical constitution of its own ingredients does the atmosphere affect the sanitary condition of man. The numerous substances which it casually contains have also an immense influence upon his health. We all know that solar light, on passing through a dark room, invariably reveals its track by illuminating the dust floating in the air, and this dust, consisting of innumerable atoms invisible in diffuse daylight, is nowhere and never absent, though, of course, extremely various in different localities both in quantity and composition. We meet with it in the Alpine valley, where Nature seems to be wrapped in universal repose, as well as in the populous city, where the stream of life casts up a perpetual turmoil; we inhale it with every breath not only in the crowded hall or in the tumultuous thoroughfare, but in the quiet of our study or in the tranquil seclusion of our garden. Inorganic matter—fine sand or ashes—is too heavy to remain long suspended in the air, and thus the floating dust of our rooms or of the atmosphere in general consists mostly, if not altogether, of organic particles. This important fact was fully proved by Professor Tyndall, who, requiring for his experiments a vessel filled with air that should contain no substance whatever capable of scattering the light in the smallest degree, caused the air that was to fill his apparatus first to pass through two tubes, the one containing fragments of glass, wetted with concentrated sulphuric acid; the other, fragments of marble, wetted with a strong solution of caustic potash. To his astonishment, the dust passed through both, which would certainly not have been the case if it had been composed in great part of inorganic and non-combustible particles.

The case was different when he made the air pass through a red-hot platinum tube; for, though previously full of particles, a beam of electric light now no longer revealed in it the least atom of floating dust, thus showing that the latter had been totally consumed, and was, consequently, of an organic and combustible nature.

As may well be imagined, this floating air-dust consists in great part of dead matter, more or less in a state of decomposition, which makes itself at once known to our olfactory organs both by the disgust we feel on entering a badly-ventilated room, and the pleasant sensation we experience when on quitting it we once more breathe the pure fresh air. But besides dead organic substances, the living sporules or germs of innumerable microscopic organisms are likewise floating in the atmosphere; and these are frequently still more detrimental to man, as they are the parents of the various contagious diseases to which he is subject. They enter his body with the air he breathes, and produce disturbance by the development of parasitic life within his frame. As a grain of wheat, when sown in a fruitful soil, gives birth to a plant competent to produce a number of similar grains, each gifted with the power of multiplying itself by reproduction, and as thus from a single seed whole fields of corn may spring, so also each epidemic literally plants its seeds, and grows and shakes abroad new germs, which, finding in the human body their proper food and temperature, finally invade whole populations. The plague which destroyed nearly all the silkworms of Europe, as well as the potato disease, have been proved to owe their vast extension to the immense multiplication of minute parasites, wafted by the currents of air from field to field and from land to land; and though no one has as yet been able to detect the germs which produce scarlet fever, or the measles, or the cholera, the whole history of these diseases leaves no doubt that they are propagated in a similar manner.

So much, indeed, is man influenced by the extraneous substances floating in the air, that it is chiefly upon their paucity or abundance that the distinction between healthy or unhealthy localities is founded.

Malaria—*aria cattiva*—the bad air, as it is called by the Italians, is the scourge of many countries which would otherwise be reckoned among the fairest on earth. It chiefly results from the decomposition of organic substances in low marsh lands, or wherever the water stagnates and gives birth to innumerable microscopic organisms. Under the volatilising influence of solar heat, the mephitic vapours, laden with the seeds of disease, rise into the air and generate a host of fevers, which sometimes slowly undermine the health of man, and at others, invading his frame with sudden fury, precipitate him into an untimely grave.

Pale cheeks, a languishing gait, a want of physical and mental energy, characterise the thinly-scattered population of the ill-famed malaria districts of Italy, which, for the greater part uncultivated and waste, present a melancholy prospect to the traveller.

The heavy autumnal rains, which generally fall during the second half of October, destroy the pernicious power of the malaria, and the atmosphere remains untainted with deleterious particles during six or seven months. But when the increasing heat of spring and a long drought split the arid soil, and the sun darts his burning rays during the long summer's day into the stagnant waters, the fine invisible and yet universally perceptible poison of the malaria spreads in the heretofore pure and healthy atmosphere. With several interruptions, this enemy of mankind reigns along the low coast lands of the Mediterranean from the mouths of the Arno or of the Cecina to the confines of Calabria; but it is nowhere more dangerous than in the Tuscan Maremmas, the Pontine marshes, and the desert plain where the ruined temples of Paestum rise in solitary majesty. Generally confined to the flat lowlands or to the neighbourhood of swamps, it often ascends with more or less intensity not only upwards into the higher valleys, but even reaches localities placed on considerable eminences, and far from all stagnant waters. Higher than 1,800 feet, however, it never rises, and even most of the hills and plateaux which only attain one-half of this height remain free from the scourge. Many an ancient seat of culture has been invaded by the malaria, and even Rome, the old empress of the world, is exposed to its inroads. As the heat of summer increases, it takes possession of St. Peter's and the Pantheon, and drives away the strangers who had come to admire the vestiges of her ancient power, or to muse among her ruins.

In Greece, also, many a seat of old historic renown has been converted by malaria into a lurking-place of death; under the shades of Delphi it waits upon the antiquarian, whom his favourite study has blinded to its terrors, and strikes him with its fatal dart.

The hotter the climate the more intense is the virulence of the morbific germs which rise from the oozy soil; and while on the borders of the lazy Schelde or the marshy

Danube they shake their victim with ague, in the tropical zone they lay him prostrate with yellow fever. Who can tell the number of Europeans that in Batavia or on the coast of Guinea have been ruined in health or rapidly snatched away by malaria? and of the bold travellers who have risked and lost their lives in the noble task of exploring the unknown regions of Central Africa, more have undoubtedly perished through the insidious attacks of the climate than through the hostility of the negroes.

The mangrove vegetation, which in the tropical zone generally fringes the low sea-shore, or luxuriates along the estuaries of rivers or in the shallow lagoons, is particularly dangerous. The tangled roots of these singular semi-aquatic plants advance in course of time over the shallow borders of the ocean, and, stemming the reflux of the tide, retain in their meshes a vast quantity of decaying animal and vegetable matter, which, forming a thick black mud, teems with noxious exhalations. In temperate Europe the neighbourhood of fens and swamps is merely unhealthy, but the malaria which ascends from the sultry morasses of the torrid zone is absolutely deadly.

Although not so noxious as the air of marshes, the atmosphere of our great towns is generally so tainted with unwholesome particles as to be evidently detrimental to the health of their inhabitants. The wealthy who reside in less densely populated districts, who have more spacious dwellings at their disposal, and generally pass a great part of the year in the country, are indeed more or less exempt from its pernicious influence; but not so the great majority of the poor, who, confined with their families to small rooms in crowded streets or narrow courts, but rarely quit the confines of the town, and are almost perpetually immersed in an atmosphere polluted with a cloud of impurities. This cloud, as Professor Tyndall shows us, is composed not only of the smoke of innumerable chimneys, but of a vast congeries of organic matter, either dead, in every stage of decomposition, or alive and pregnant with contagious disease. M. Flammarion tells us that it is necessary to rise at least to an altitude of 1,600 feet before an aeronaut can consider himself quite free from Parisian dust, and a similar cloud is hanging over every city, while even the comparatively pure air of villages is charged with impurities of various kinds. A pale bluish haze rests upon it, and when a breeze blows over it its canopy of dust may be seen wafted for a mile or two before it is finally dissipated in the purer atmosphere. However ordinary daylight may permit it to disguise itself, a sufficiently powerful beam of light causes the dust suspended in the air of our cities to appear almost as a semi-solid. 'Nobody,' says Professsr Tyndall, 'could in the first instance without repugnance place the mouth at the illuminated focus of the electric beam and inhale the thickly-massed dust revealed there. Nor is the repugnance abolished by the reflection that, although we do not see the floating particles, we are taking them into our lungs every hour and minute of our lives.'

No wonder that children growing up in an atmosphere like this are so frequently scrofulous and weak, and that the sallow faces of old and young so often betray ill-health; no wonder that convalescents so slowly recover their vigour in the tainted atmosphere of cities. How different in the pure air of a healthy country district, where rosy cheeks and sparkling eyes show health and energy in every countenance! Such, indeed, is the force of habit that the dweller in towns grows quite insensible to the bad quality of the air he breathes, but its corruption plainly shows itself to those who are accustomed to pass their lives in a purer atmosphere. Thus the Scotch Highlander frequently experiences a feeling of oppression on entering Glasgow; and the true Bedouin, when business calls him to visit a crowded city, is always known by bits of cotton in his nostrils, or his kerchief tightly drawn over his nose, a heavy frown marking extreme disgust. Declining the shelter of a house, he passes the night in a garden or public square rather than breathe the confined air of an apartment.

The influence of climate on the human health and character is so manifest that it could not fail to engage attention at a very early age. The stolidity of the Bœotians was attributed by Grecian philosophers to their opaque air, and the sharp wits of the Athenians to the nimble breezes of Attica. The melancholy character of the Etruscans was also supposed to be in some measure due to the telluric exhalations mingling with the atmosphere of their volcanic country.

The mild and moist insular climate of Great Britain reflects itself in the more sedate character of its inhabitants, while the dry climate of North America, liable to enormous variations of temperature, produces extreme excitement. To this the Americans are no doubt indebted for that 'go-ahead' activity which has done so much for their prosperity, but at the same time it is the cause of the painful neuralgic diseases to which they are subject. The florid complexion and the rounded limbs of the Britons may also be traced to the effect of climate, as well as the lank frames and sallow complexion which characterise a great number of our trans-atlantic cousins.

Travellers in foreign lands repeatedly mention the mysterious influence of climate upon the state of their spirits. In the lake regions of Central Africa, the fine, cool mornings, the clear, warm sun, and the deliciously cold nights which render the climate truly enjoyable after the rainy season, might be supposed to produce an exhilarating effect; yet amidst scenes of beauty, Captain Burton felt 'that strange inexplicable melancholy of which most travellers in tropical countries complain.'[1] 'In this Nature,' adds the celebrated voyager, 'all is beautiful that meets the eye, all is soft that affects the senses; but she is a syren whose pleasures soon pall upon the enjoyer. The mind, enfeebled perhaps by an enervating climate, is fatigued and wearied by the monotony of the charms which haunt it; cloyed with costly fare, it sighs for the rare simplicity of the desert.' Kittlitz[2] likewise describes the singular influence of the climate of Kamtschatka on the feelings of strangers in producing either a morbid exaltation or an equally unaccountable depression of the spirits. He mentions the case of Admiral Krusenstern, a rough old seaman, generally very little prone to indulge in the melting mood, who, in a sudden paroxysm of home-sickness, shed tears at the sight of the Kamtschatkan birch—a tree which is not even very like the European species. An officer belonging to Lütke's expedition, whohad previously been most zealous in the performance of his duties, was all at once seized with such an invincible longing to return to his native country that he resolved to leave the ship, and, in spite of all remonstrances, actually returned to Russia by land. The suicide of Admiral Price is also attributed by Kittlitz to the strange influence of the Kamtschatkan climate. The veteran seaman, on seeing the difficulty of attacking Petro Pawlowsk by land, was immediately seized with a profound melancholy, and seemed to foresee the unfortunate issue of the undertaking. But instead of postponing the attack, or making other dispositions, which he might easily have done, he gave orders for landing on the following morning, withdrew into his cabin, and blew out his brains. Kittlitz himself felt at first so extravagantly delighted with Kamtschatka that it seemed to him a paradise, and he determined to remain there the whole summer; but his exultation soon subsided and changed into the opposite extreme. From these and many other facts he draws the inference that a state of unusual joyful excitement, succeeded by an extreme relaxation and depression, must be considered as an endemic disease of the eastern coast-lands of the old continent.

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[1] 'The Lake Regions of Central Africa,' vol. ii. p. 130.

[2] 'Reise nach der russischen Amerika,' 1859.

In our own country we meet with similar instances of the depressing influence of particular climates on nervous temperaments. Dickens describes as follows his state of mind after a few weeks' residence in Bonchurch:—'The first salubrious effect of which the patient becomes conscious is an almost continual feeling of sickness, accompanied with great prostration of strength, so that his legs tremble under him, and his arms quiver when he wants to take hold of any object. An extraordinary disposition to sleep (except at night, when his rest, in the event of his having any, is broken by incessant dreams) is always present at the same time; and, if he have anything to do requiring thought and attention, this overpowers him to such a degree that he can only do it in snatches, lying down on beds in the fitful intervals. Extreme depression of mind, and a disposition to shed tears from morning to night, developes itself at the same period. If the patient happens to have been a good walker, he finds ten miles an insupportable distance, on the achievement of which his legs are so unsteady that he goes from side to side of the road like a drunken man. If he happens to have ever possessed any energy of any kind, he finds it quenched in a dull, stupid languor.'[1]

All these cases prove that between the various atmospherical influences which we designate by the name of climate, and the vital activity of the nerves, there must be a connection which science has as yet not been able to account for, but the effects of which are too often felt to be denied.

Ever since Hippocrates, a change of climate and air has been considered by physicians as a most powerful remedy, and the justness of this opinion is confirmed by daily experience. The improvement which takes place in the health of the inhabitants of large towns after even a short residence in the country, is very apparent, and wonderful cures, unobtainable by any other means, are not seldom effected by the removal of patients to another climate. Fortunately we live in times which render the application of this sovereign remedy much easier than it has ever been before. The locomotive and the steamboat have now brought the mountain and the sea, or the mild breath of a sunnier land, within the convenient reach of thousands who would otherwise have been attached to the glebe, and enable them to exchange the dust of towns or the blasts of winter for the invigorating atmosphere of the Alps, the bracing sea breeze, or the genial warmth of the south.

Among the qualities to which the sea air owes its preeminently salutary influence on the health of man, its great purity is no doubt the most important. The extraneous particles without number which defile the atmosphere of cities, and convert it into a hotbed of ill-health, are absent from the unadulterated air-currents which sweep over the wide ocean, and this alone would suffice to render it highly salubrious. The greater uniformity of its temperature, which, for reasons previously mentioned, mitigates both the heat of the day and the evening's chill, has likewise a most beneficial effect on deteriorated constitutions, as well as its moisture, which tempers the sharpness of the wind, and renders irritable respiratory organs less liable to suffer from catarrhal affections. To these well-known salubrious qualities of the sea air, the influence of saline particles, of iodine, of a greater quantity of ozone, or of a peculiar electrical condition, &c., may possibly add its beneficial effect. Thus much is certain, that it shows itself a source of health and consequent happiness to thousands.[1]

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[1] Forster's 'Life of Dickens,' chap. xlii.

In purity and invigorating qualities it is rivalled by mountain air, which, fortunately, is becoming more and more appreciated, as is fully proved by the constantly increasing number of sanatoria and pensions in the Swiss Alps, where the valetudinarian inhales health with every breath, and, at the same time, enjoys the sublimest scenery. 'Happy the man,' says Horace, 'who, free from the yoke of business, ploughs his paternal fields,'

Beatus ille, qui procul negotiis,
Paterna rura bobus exercet suis;

and surely, had the favourite of the Muses and Graces lived in our age, he would have proclaimed him happier still, who, relieved from the weight of affairs, spends his summer on the brow of the Righi, in the valley of Maderan, at Engelberg, or wherever on a sunny Alpine slope the breast expands in the purest air, while the enchanted eye roams over a vast panorama resplendent with all the beauties of Nature.

While a warmer climate is more conducive to the health of certain constitutions, others feel themselves better in a colder atmosphere. According to Nordenskjold, not a single case of illness or catarrh occurred during the whole summer among the crews of all the ships he met with in Spitzbergen, although more than once some of the men fell into ice-cold water and remained for some hours in the boat without changing their clothes; and this he attributes to the unrivalled purity of the air and its invigorating effects. A winter spent in the valley of the Engadine, at an elevation of about 5,000 feet, where the thermometer frequently falls to −20°, but where the absence of wind during the severest cold and the serenity of the sky render the lowest temperature far more pleasant to the feelings than the chilly mists of November in our foggy island, has also been found to strengthen weak and nervous individuals in a remarkable manner, as well as a summer residence in the Alps, at heights of 7,000 feet or more. Perhaps the time is not far distant when we shall hear of a sanatorium in Spitzbergen, or somewhere about the limits of perpetual snow in the Alps; so much is certain, that a more exact study of climates or of physical geography will be required in future of medical practitioners.

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[1] For further particulars see my practical 'Treatise on Sea Bathing and Sea Air.' J. Churchill.

If a suitable change of air is in every case an excellent means for preserving or improving the health, it is more particularly so where a weak or affected breast gives menacing signs of consumption. Unfortunately, the removal to a more southern climate is too often retarded until the disease has made such progress as to be past all cure; but where it is still in its first stage, or where it is to be feared that its latent seeds may develop themselves under unfavourable external circumstances, there is, beyond all doubt, no better means for warding off its insidious attacks than the exchange of a cold and misty climate for a residence in a more sunny land.

This truth is now so universally acknowledged that, as soon as the falling leaves and the prolonged shade of evening announce the approach of winter, we see thousands of weak-breasted patients prepare, like birds of passage, for a flight to the genial south. There they escape the danger of catching cold, which is hardly to be avoided in the blustering north; and enjoy, besides, the inestimable advantage of being able to spend many hours in the open air, while, at home, they would either be compelled to remain within doors, or to expose themselves to the caprices of a fitful atmosphere. A moderate exercise in the mild and temperate air improves their general health, and affords relief to the suffering organs by promoting a more free and regular circulation of the blood throughout the whole economy. This change for the better, as well as the enlivening change of scenery, has an excellent effect on their spirits, which again reacts favourably on their health.

Thus, whoever is sufficiently favoured by fortune to be able to exchange winter for summer, should by no means hesitate to preserve his impaired health from the evil effects of a rigorous climate by a timely migration to the south. But what spot is he to choose? Where can he best escape every hurtful change of temperature? The choice is indeed difficult; for if seven cities disputed the honour of having given birth to Homer, at least a hundred localities, all eager to attract the moneyed patient, loudly proclaim the excellence of their unrivalled situation.

One of the most famous places of winter resort is Nizza, whose climate is, however, in many cases, far from being salutary. For, although the temperature seldom falls below the freezing-point of water, and that only during the night, so that vegetation is never completely interrupted, and even palm-trees grow in the open air, yet chilly blasts descending from the mountains are by no means uncommon. In the spring, particularly in March and April, the frequent easterly winds are rendered doubly unpleasant by the contrast with the generally mild and genial state of the atmosphere. They often blow with considerable violence, and are accompanied with mists and clouds. Nizza is tolerably sheltered from the north-east wind or the Mistral, the plague of Provence; but although this wind is never very strong or only makes itself sensibly felt when blowing more from the west, the dryness of the air during its prevalence is unpleasant. No wonder, then, that catarrhal and rheumatic affections and inflammation of the lungs are extremely common at Nizza, and that in the hospital one-fourth of the deaths proceeds from pulmonary consumption!

We surely need no better proof that a winter residence in a place like this is not advisable for patients with weak respiratory organs.

Similar objections may be raised against Pau, Hyères, and other localities in the south of France, which are all still too far to the north, or too much exposed to the chill blasts from the Alps or Pyrenees, to be eligible residences for the candidates for consumption. Even in Naples, cold and sharp irritating winds frequently blow in spring, and are the more trying to the constitution from the contrast with the burning heat of the sun.

Malta and the Sicilian coasts are, no doubt, more advantageously situated, but even the mildest hibernal climate in Europe must cede the palm to Madeira, which, from its insular position, far from all continental influences, enjoys the inestimable privilege of a more equal temperature during the whole course of the year. The day contrasts less with the night, one day less with another, one season less with that which is to follow. The heat of summer is mitigated by the north-east winds which blow almost uninterruptedly, and is seldom so oppressive as the heat in Europe. Sultry days are very rare in Madeira, and the atmosphere is free from smoke or dust. The summer is, in fact, so temperate, that a physician who resided in Madeira for the sake of his own health, declared that season to be even more favourable for pulmonary patients than the winter.

The rainy season sets in with west or south-west winds about the end of September or the beginning of October. In November the weather clears up, and continues to be fine and mild till the end of December. About this time some snow generally falls upon the mountains, and some rain at Funchal; north-west winds sometimes blow, and the weather is more or less damp in January and February. Fogs, however, are unknown.

The spring is, in Madeira, as it is elsewhere, the most unfavourable season for a patient, and makes, even there, some precautions necessary. March is windy, and April and May rainy.

The physical condition of the inhabitants speaks well for the mild character of the climate; for, though a hard-working, poor, and ill-fed race, they are uncommonly strong and robust. For all who have reason to fear incipient consumption, or in whose family the disease is a fatal heirloom, and requires early precautions to be taken, a prolonged residence in Madeira is thus highly advisable; but it is of the greatest importance that the removal be not deferred too long, for, when consumption has once made serious inroads on the constitution, its progress is only accelerated by the journey.

The land of the Pharaohs rivals, and perhaps even surpasses, Madeira as an eligible winter residence for delicate constitutions. Lower Egypt has one of the finest climates in the world. The summer is not too warm, the winter not too cold; the vegetation is superb, and it is no small enjoyment for a child of the north to wander in orange-groves, or to sit under the topes of palms. At the same time, a sky of never-clouded serenity smiles upon the fertile valley of the Nile, no thunderstorm ever sets fire to a building, no tornado ever uproots the fruit-trees, no torrents of rain ever sweep over the fields in devastating floods. A genial warmth reigns the whole year round; the thermometer generally ranges between 15° and 20° R. Among the Egyptians pulmonary consumption, which destroys about one-fifth of the population of Italy, is an unknown complaint.

The rapid and perpetual change of climate acts as beneficially upon the body of a traveller as the constant succession of new and interesting scenes upon his mind, and, by rousing both his corporeal and spiritual faculties, strengthens his whole frame, and enables it to oppose a more energetic resistance to the encroachments of disease. For this reason we all feel an instinctive pleasure in mere locomotion, and whoever has once been sauntering along the highways and byways of Europe experiences, at every return of the travelling season, a longing desire to renew his wanderings, which, though often attended with fatigue and discomfort, have been so rich in present enjoyment and agreeable reminiscences.

Fortunate above all, the youth who is at liberty to stray among the Alps, now listening to a mountain torrent as it roars through a romantic glen, and now planting his foot upon a proud eminence—the ideal lord and conqueror of all he surveys. Strengthened in body and mind, he returns to his usual duties far better able to fulfil them than if he had spent his leisure among the frivolous or enervating amusements of a capital.

CHAPTER XXXII.

FLYING MACHINES.

The Desire to Fly Natural to Man—The Legend of Dædalus and Icarus—John Baptist Dante—Oliver of Malmesbury—Besnier—The Marquis de Bacqueville—Bernouin—The Abbé Desforges—Berblinger—Jacob Degen—De Groof—Monck Mason on Flying Machines.

'WE feel in us,' says Goethe,[1] 'the germs of faculties which we must not expect to see developed in this life, and one of these is undoubtedly that of flying. When formerly the clouds, sailing high above my head, made me long to accompany them to distant countries, I now feel a still more intense desire to follow them, when, standing on a lofty peak, I see them wafted beneath me. How I long to plunge into the infinite aerial space, to hover over the dreadful abysses, and to alight on some inaccessible rock! How wishfully I follow the eagle gliding over precipices and forests, or drawing wide circles round the peak to which he has confided his nest and his young! Am I then condemned for ever only to creep upwards, to remain attached to the highest rock as if it were the lowest ground; and, when I have with incredible difficulty attained the summit, to cling to it anxiously, to shudder at the return, and to tremble at a fall?'

From this desire, so natural to man, the thought necessarily arose whether he might not possibly acquire by art pinions which have been denied to him by Nature? If his inventive genius has enabled him to plough his way through the ocean, and to emulate the fishes in their own domain, why should he not be able to learn from the birds the secret of their flight, and to conquer the empire of the air, after having made the seas obedient to his will?

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[1] 'Letters from Switzerland.'

The old Greek fable of Icarus is probably the poetically embellished narrative of an attempt of this kind made in times of remote antiquity. Dædalus the artist, according to the Attic myth, made for himself and his son Icarus artificial wings of feathers fastened with thread and wax, in order to escape over the sea from the anger of Minos. Before they ventured upon their perilous journey, the prudent father warned the inexperienced youth not to fly too low, lest the moisture of the sea might encumber his wings; but also not to soar too high, that the wax which cemented the feathers might not melt by coming too near the sun. At first the aerial journey proceeded as well as could be wished; Dædalus flew on before, and Icarus followed, carefully attending to the wise precepts of his father. Soon, however, youthful presumption led him on, his flight became bolder and bolder, and, leaving the safe path of his experienced guide, he flew upwards to the skies. But his presumption was dreadfully punished; for the wax of his wings melted in the rays of the sun, their feathers dropped, and the loss of his pinions precipitated him—*vitreo daturum Nomina ponto*—into a watery grave.

Since the times of Dædalus many an unlucky inventor has no doubt tried to imitate the flight of birds by a more or less ingenious mechanism, but they all found to their cost that it is easier for man to soar aloft on spiritual pinions than to raise by his own muscular exertions his heavy corporeal weight into the air; and the names of but few of the imitators of the old Greek master have escaped oblivion.

Thus, in the seventeenth century, John Baptist Dante, an excellent mathematician, trusting to an apparatus of wing-like oars, launched himself from a high tower in Perugia. But the mechanism with which he managed one of his wings having failed, the new Dædalus, as he was called by the Italians, fell upon a roof and broke his thigh. This accident seems effectually to have cured his ardour for aerial voyages, for, though we are told that he had previously succeeded in flying several times over the Lake Thrasymenus, we do not hear of his having ever again trusted to his wings.

A similar accident happened to Oliver of Malmesbury, a learned English Benedictine monk, who was reputed extremely clever in the art of foretelling futurity, but failed in foreseeing the unfortunate result of his own aerial flight. He made wings after the description which Ovid has left us of those of Dædalus, bound them to his arms and legs, and, agitating his Icarian pinions, sprang from the top of a high tower. But his wings sustained him only a short time in the element he had vainly hoped to make his own; and, falling at the foot of the tower, he broke both his legs, and ever after led a languishing life.

In the year 1678 a flying machine invented by Besnier, a locksmith of Sable, in France, attracted universal attention. It consisted of four wings or large flaps, attached to the extremity of levers resting on the shoulders of the man, and moved alternately by the hands and feet, so that while two of them were raised the two others were depressed. By means of this aerial rowing, Besnier is said to have let himself down from considerable heights in a diagonal direction, but not to have been able to raise himself. He is also said to have been able to cross rivers by flying through the air. So much is certain, that the practical use of his machine cannot have repaid the trouble of setting it in motion, for no one has ever thought of adopting it.

We are told that the illustrious Leonardo da Vinci not only knew, but actually practised, the art of flying through the air. Fortunately for his fame, the great man has better-authenticated claims to immortality.

In the year 1742 the Marquis de Bacqueville, according to a notification which he had made to that effect, rose in the sight of the assembled multitudes of Paris from his own residence on the Quai des Théatins, and directed his course across the Seine towards the gardens of the Tuileries, whither he had signified his intention of proceeding. At first he appeared to advance with tolerable steadiness; but, when about half-way over, his wings ceasing to act in the manner necessary for his support (no doubt from his strength giving way), he sank to the ground 'like a wearied bird,' and was precipitated against one of the floating huts which line the arches of the Port Royal, whereby his leg was broken, and other serious injuries inflicted upon his person.

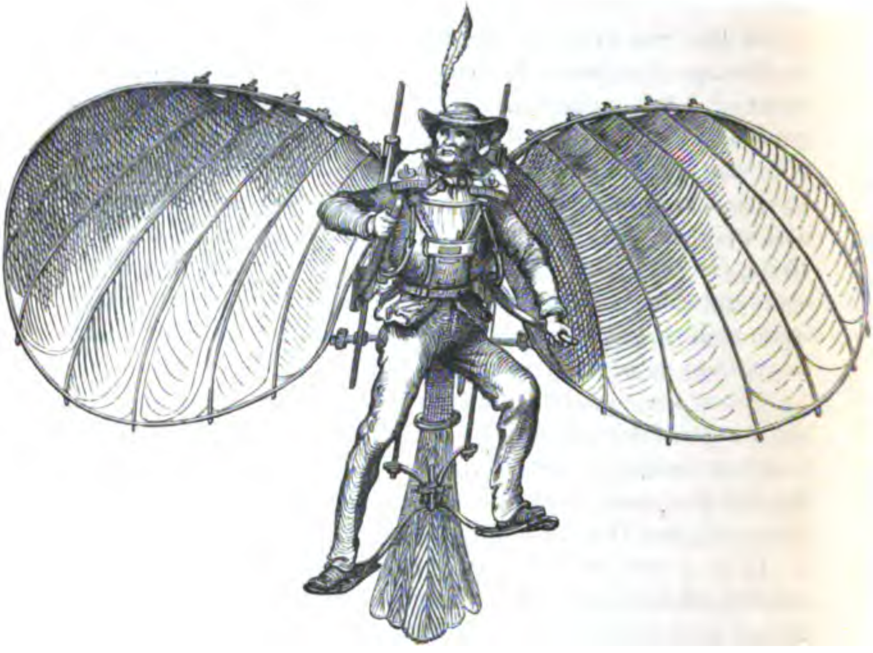
The Marquis, like his predecessors Dante and the monk Oliver, escaped without the loss of his life; but a 'flying man,' named Bernouin, who, in 1673, wished to astonish the public at Frankfort by an aerial excursion, was less fortunate, as he broke his neck in the attempt.

In the year 1772 the Abbé Desforges, canon of St. Croix, at Etampes, announced, through the journals, the experiment of a flying chariot. A great number of spectators appeared on the appointed day to witness the ascent of the canon, who was seen seated in his machine on the tower of Guitel. It was a kind of boat or gondola, 7 feet long and 2½ broad, and weighed, with its broad wings, 48 lbs., so that, with its living freight, it had to carry 213 lbs. The canon had foreseen and calculated all possible contingencies, and reckoned upon sailing through the air at the rate of 30 leagues in an hour, in spite of wind and weather!

When the signal for his departure was given, he unfolded the wings of his machine, and set them in motion with the greatest rapidity; 'but,' says an eye-witness, 'the more he flapped the more heavily his machine seemed to rest upon the earth, and the more unwilling to leave it.'

It is a curious fact that while pensioned captains, shoemakers, and bankrupt merchants seem to have been chiefly busied with the discovery of the perpetuum mobile, tailors have more specially directed their thoughts to the invention of flying machines. A member of this 'worshipful company,' named Berblinger, engaged, on June 11, 1811, to fly from a bastion at Ulm across the Danube, in the presence of the King of Würtemberg. But whether his courage failed him when the decisive moment came, or else some defect was discovered in his machine, he begged to put off the trial to the next day, when he actually launched on his aerial journey, which ended with a cool bath in the Danube.

About the same time all the German newspapers were filled with accounts of the flying machine of Jacob Degen, a watchmaker of Vienna. It consisted of two powerful flaps, which were fastened to a yoke round his neck, and provided with a mechanism which was set in motion by the hands and feet, and served to raise and depress them like the wings of a bird. Such was the man's confidence in the success of his machinery, that he attempted to rise, like a lark, from even ground; but, in spite of his utmost exertions, he was not strong enough to overcome the power of gravitation, and remained fixed to mother earth. He finally took a balloon to his aid, and showed himself at Paris, where, suspended from the gondola of an aerostat, he did his best to steer. But his unlucky wings proved as ineffectual as ever, and poor Degen, covered with ridicule, retired from the scene of public life, and was never after heard of.



JACOB DEGEN.

On July 9,.1874, De Groof, a Belgian, trusting to a pair of wings of his own invention, leaped from a balloon, in which he had ascended at Cremorne Gardens, and was killed by the fall.

The physical construction of the birds, or of the bat, whose flight he vainly strove to emulate, might have convinced this unfortunate man of the utter vanity and uselessness of his efforts. Had he been able, instead of adding to the weight of his body by a cumbersome machinery, to reduce it to one-tenth, while the muscles which set the arms in motion swelled to ten times their actual size and strength, he might perhaps have made the trial with better success, though, at all events, he would have been but a very indifferent flyer, the whole form of his body being by no means adapted by Nature for aerial locomotion.

'The variety and delicacy of the physical exertions,' says Mr. Monck Mason,[1] 'by which the bird is enabled to execute its evolutions, are indeed truly astonishing, and, when we compare its condition in that respect with the clumsy efforts of man's most successful imitations, we cease at once to marvel at his failure or at their success. In the one case, we have a body composed of a variety of parts, every one of which is endowed with vitality, susceptible of distinct and separate motions, obedient to the slightest impulse of the will, constructed of materials made expressly for the purpose, and, from constant habit and natural aptitude, capable of executing the most complicated movements with a security, efficacy, and despatch that seem almost to anticipate the inclination by which they are ordained; in the other, could we even accomplish his equipment, and give him power to avail himself of his means, we should still have an object composed of *substitutes* instead of *attributes*—a heterogeneous mixture of remedies to supply defects, and mechanical contrivances to aid physical inefficiencies, obliged by its construction to operate in the mass, or, if susceptible of a partial movement, only rendered so through the intervention of the most cumbrous and complicated machinery, constantly liable to disorder, and involving irremediable destruction to the whole from the slightest injury or interruption to the action of any one of its parts.'

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[1] 'Aeronautica.'

As man is actually built, it has been calculated that, to carry his heavy body through the air, he would require wings of a surface equal to 12,000 or 15,000 square feet, with which he would have to strike the air several times in a second—an exertion which even the sinewy arms of a Hercules would be unable to perform.

CHAPTER XXXIII.

THE BALLOON.

Father Lana—Lichtenberg—Cavallo—Joseph and Stephen Montgolfier—Charles and Robert—The 'Globe'—The Wise Men of Gonesse—Pilâtre de Rozier, the First Aeronaut—Aerial Voyage of Charles and Robert—The Montgolfieristes and Charlistes—Extravagant Expectations—James Wilcox—James Tytler, the First English Aeronaut—The 'Flesselles' Balloon—Madame Thible—The Duc de Chartres—The Balloon at Constantinople—Blanchard's Aerial Voyage from Dover to Calais—Tragical End of Pilâtre de Rozier—The Parachute—Garnerin—Madame Blanchard—Napoleon's Coronation Balloon—Count Zambeccari—His Aerial Adventures—Bittorff.

ALTHOUGH every attempt to imitate the flight of the bird or of the bat with artificial wings has been necessarily doomed to signal failure, yet man has been enabled to accomplish the task in another manner, and, by means of a balloon filled with a light gas or with rarefied air, to raise himself higher in the atmosphere than the eagle ever flew.

The invention of the air-balloon is indeed of so recent a date, that even now there may be persons still living who witnessed the ascent of the first Montgolfière; but as far back as the seventeenth century we find the principle on which its construction is based engaging the attention of bold and inquisitive minds.

Thus, soon after Otto von Guericke's invention of the air-pump, Father Lana, an Italian Jesuit, published a treatise,[1] in which, reasoning from the undeniable fact that if a globular vessel were exhausted of air it would weigh less than before, he affirmed that a metalline vessel might be made so large, that when emptied of its air it would be able not only to raise itself but to carry up passengers along with it.

[1] 'Prodrome dell' arte maestra.' Brescia, 1670.

To prove the possibility of realising what he called 'the master art,' he brought forward a number of calculations; but, though his theory was correct, the means proposed were certainly insufficient to accomplish the end; for a vessel of copper, sufficiently thin to float in the atmosphere, would be utterly unable to resist the external pressure. As this was demonstrated by skilled mechanicians, no attempt was made to put the learned father's project to the test.

About a hundred years later, in 1766, we find the thought occurring to Dr. Black, that perhaps a thin bag, filled with the inflammable gas (hydrogen) recently discovered by Cavendish, might be buoyed up by the common atmosphere, which is about fourteen times heavier; but Professor Lichtenberg of Göttingen, and Tiberius Cavallo, an Italian settled in England, were the first who made experiments on the subject. Lichtenberg (1781) constructed a small balloon, four inches in diameter, from the allantois of a goat, which rose in the air when filled with hydrogen. Cavallo first tried bladders; but the thinnest of these, however well scraped and prepared, were found too heavy. He then tried Chinese paper; but that proved so permeable that the vapour passed through it like water through a sieve. His experiments, therefore, made in the year 1782 proceeded no farther than blowing up soap-bubbles with inflammable air, which ascended rapidly to the ceiling and broke against it.

Thus the discovery of the art of aerostation seemed on the point of being made in Germany or in England, when it was all at once announced in France from a very unexpected quarter.

Two brothers, Joseph and Stephen Montgolfier, paper manufacturers at Annonay, a small town in the Département de l'Ardèche, had turned their attention to aerostatics as early as the middle of the year 1782. The idea of the invention was first suggested by the natural ascent of steam and clouds in the atmosphere, and its execution hastened, we are told, by the wish to devise some means of relieving Gibraltar.[1] Their design was to form an artificial cloud, by enclosing steam in a bag, and making it carry up the covering along with it. But, the bag merely rising to fall again, they next thought of applying hydrogen. Their paper balloons, however, let the light gas escape too soon, and, as its production was moreover extremely expensive, they finally came upon the singular idea of inflating them by the burning of a mixture of damp straw and wool, which, as they thought, would form an *electric* vapour or smoke, from which they expected better results. The first successful experiment of raising a balloon by this new method was made in November 1782 at Avignon, where the brothers were at that time residing.

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[1] 'Correspondance littéraire de Grimm et Diderot,' tom. xiii. p. 239-248.

By applying their burning mixture to the lower aperture of a fine silk bag, containing less than two cubic mètres, the air was rarefied as it would have been by the combustion of any other substance, and the bag, ascending in the atmosphere, struck rapidly against the ceiling of the room in which the trial was made.

After their return to Annonay, the brothers repeated their experiment in the open air, and the bag rose to the height of about seventy feet.

Sure of their principle, an experiment on a more enlarged scale was now projected, and a new machine, containing about 650 cubic feet, was made, which, with buoyant force, broke the cords that confined it, and fell down upon the neighbouring hills, after having risen to the height of about 600 feet. Another balloon of 35 feet in diameter rose about 1,000 feet high, and fell to the ground three-quarters of a mile from the place where it ascended.

As yet all these experiments had been made in private; but the brothers, emboldened by their success, now resolved to make a public exhibition of their discovery. On June 5, 1783, a vast concourse of people assembled in a field near Annonay to witness the ascent of an immense linen bag lined with paper, and containing upwards of 23,000 cubic feet. The operation was begun by burning chopped straw and wool under the aperture of the empty machine, which soon began to swell, and after being set at liberty rapidly ascended into the atmosphere to a height of about 6,000 feet. It was then seen to describe a horizontal line of 7,200 feet, when, having spent its force, it gradually descended to the earth so lightly as not to damage the corn and vines on which it fell. An indescribable enthusiasm hailed its triumphant career, which promised to open a new and vast field to the enterprise of man. The French Academy of Sciences at once named a commission to report upon the wonderful experiment; but the Parisians, not caring to wait for its decision, immediately raised 10,000 livres by public subscription, and entrusted Messrs. Robert, two clever mechanicians, and M. Charles, an eminent professor of experimental philosophy, with the construction and management of a balloon. The Montgolfiers had indeed intended to make a secret of their invention; but, as it could not be concealed from the merest tyro in physics that a bag filled with any kind of fluid lighter than the common atmosphere must necessarily rise in it, inflammable air was naturally selected by their rivals for their purpose. Its production, however, was found to be a matter of no small difficulty, as the gas had never yet been evolved in such a quantity as to fill a balloon, though only of 13 feet diameter. It must be remembered that, chemistry being then in its infancy, the apparatus used for its preparation was such as would provoke the smile of a Bunsen or a Liebig. Iron filings and water were put into a cask, the lid of which had two apertures, one for the reception of a leathern pipe destined to convey the hydrogen gas into the balloon, the other closed with a cork for the gradual introduction of sulphuric acid.[1]

The insufficiency of this apparatus soon became apparent, for, after a whole day's labour, one-third part only of the balloon had been filled. At the same time the heat evolved during the chemical process was so great that a quantity of steam saturated with acid vapours, which threatened to corrode the lutestring varnished over with caoutchouc, of which the balloon was composed, rose along with the gas. Owing to this clumsy way of operating, an enormous quantity of hydrogen was lost, so that it required four days and no less than 1,000 pounds of iron and 500 pounds of sulphuric acid to fill a balloon scarcely weighing twenty pounds. An improvement was, however, soon made in the preparation of the inflammable gas, by first passing it through a vessel filled with cold water, which condensed the acid vapours before entering the balloon. This slow process was of course a severe trial of patience; but on the second day the 'Globe,' as the balloon was called, though not half filled, gave such evident signs of its impatience to ascend, that no doubt could be entertained of its ultimate ability to soar into the air. On the fourth day it was conveyed from the workshop of the brothers Robert, where it had been inflated, to the Champ de Mars, where its ascent was to take place. Like a desperate criminal striving with ungovernable fury to burst his fetters, the innocent 'Globe,' tied upon a truck and accompanied by policemen and torchbearers, was transported by night through the streets of Paris, to the great astonishment of the people, who, though accustomed to strange sights, had never witnessed such a spectacle before. The large size and singular form of the object thus mysteriously conveyed, the silence, the unusual hour, all combined to give to this nocturnal procession a weird and ghost-like character, so that the hackney coachmen who met it stopped their horses, and, probably mistaking it for a religious ceremony, reverentially took off their hats, and remained uncovered while it passed.

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[1] When sulphuric acid, water (which consists of oxygen and hydrogen), and iron filings are brought into contact, the water is decomposed, its oxygen, uniting with the iron and the oxide thus produced, combining with the sulphuric acid so as to form sulphate of iron or copperas, while the disengaged hydrogen, which is about 14·4 less dense than common air, escapes.

On August 27, at six o'clock in the evening, the ascent of the 'Globe' at length took place. Astronomers were watching in various places in order to measure the height to which the balloon would rise, and cannons were fired to announce the successive stages of its departure, of its losing itself in the clouds, of its reappearance above them, and of its final vanishing from sight. The enthusiastic applause of more than 200,000 spectators accompanied it during the various evolutions of its aerial flight, and, although torrents of rain fell at the time, the most elegantly-dressed ladies kept following it with their eyes as long as it could possibly be distinguished. In fact, all those who witnessed its ascent instinctively felt it to be a new and important conquest of the human mind.

After a short voyage of three-quarters of an hour, the course of the balloon came to a premature end about five leagues from Paris. The brothers Robert, contrary to the advice of their better-informed colleague, Professor Charles, had inflated it with as much gas as it would hold, so as to give it an elegant, well-rounded form. The consequence was that, as it rose into the higher and lighter strata of the atmosphere, the distended gas burst its envelope, and caused its precipitate descent near the quiet village of Gonesse, whose inhabitants, not having the least idea of what it possibly could be, were struck with amazement as they saw it descending from the clouds. In their terror they ran for advice to the village priest, who, no less bewildered than his parishioners, determined to exorcise the enigmatical monster, and, heading a procession of country folk, marched out against it. Taking a most circuitous route, they at last came near the spot where lay the disabled and half empty 'Globe,' vibrating and shuddering with the slightest breath of wind, so that it might well be mistaken for some fabulous animal panting for breath. Approaching it 'with timorous steps and slow,' the irresolute band, still hoping that it would fly away, tarried a while without opening hostilities, until at length a village hero, whose name history has not brought down to us, fired a gun at the palpitating monster. The charge of shot tearing the envelope still more, caused the remainder of the gas to issue, and the balloon to flatten down rapidly. At this moment, everyone feeling his courage rise as the enemy collapsed, now rushed forward with true French *élan* to lacerate or belabour the wounded creature with pitchfork, flail, or cudgel. The beautiful balloon, which had cost so much time, trouble, and expense, which erewhile had risen so triumphantly into the air, the admired of all admirers, thus became, by a woeful change of fortune, the victim of ignorant clowns, who crowned their Vandalism by tying its mangled remains to the tail of a horse, and ignominiously dragging it across the fields.

The next day the Government, in order to prevent a repetition of so disgraceful a scene, published a 'Notice to the public on the ascent of balloons into the air,' in which it was explained that they are not flying dragons or Apocalyptic monsters, but merely globes of silk inflated with gas, which, far from being dangerous, would no doubt become of great use to society.

Thus ended the short but glorious career of the first balloon filled with hydrogen, which, to distinguish it from the Montgolfière, or fire-balloon, was named the 'Charlière,' after the distinguished savant who first launched it into the air.

Etienne Montgolfier, who had meanwhile been invited to Paris by the Academy of Sciences, to repeat his experiments at their expense, was now more anxious than ever to hasten the construction of a large balloon, with which he hoped to eclipse the fame of his rivals. In a preliminary experiment this machine lifted up from the ground eight persons who held it, and would have carried them to a greater height than might have been agreeable if more had not quickly come to their assistance. Next day (September 13, 1783) the experiment was repeated in presence of the members of the Academy, and attended by the usual success. The balloon, filled by the combustion of fifty pounds of straw made up in small bundles, upon which about twelve pounds of chopped wool were thrown at intervals, soon swelled, strove to ascend, and immediately after sustained itself in the air, together with a load of between 400 and 500 pounds. It was evident that if set at liberty it would have soared into the clouds; but, as the experiment was to be repeated in the presence of the king, the cords which held it were not cut. In consequence, however, of a violent rain and wind which happened at this time, the machine was so far damaged that it became necessary to prepare a new one, which, not to keep royalty too long waiting, was completed in four days and four nights.

On September 19, 1783, this new balloon, which, in spite of its large size (60 feet in height and 43 in diameter) and the short time allowed for its construction, was much more solid than the first, and by the richness of its decorations did honour to French taste, was ready to rise in the great courtyard of the Château de Versailles, where a large platform under which the operations for filling it with heated air were to take place had been erected for its reception.

Early in the morning of this memorable day in aerostatic history, the road from Paris to Versailles was crowded, as may well be supposed, with innumerable carriages and pedestrians all eager for the sight, and by noon all the avenues, roofs, and windows from which the ascent of the balloon could possibly be seen were thronged with a dense mass of 600,000 spectators. At one, the firing of a cannon gives notice that the filling of the balloon is about to begin, when suddenly the inert mass which lay folded and collapsed upon the platform is seen to swell, to rise, and to expand into a magnificent globe, energetically striving to burst the numerous ropes which attach it to the earth. The firing of a second cannon now announces that all preparations are completed; and at a third shot its bonds are severed, and it rises majestically into the air, carrying along with it in a wicker cage a sheep, a cock, and a duck. The full success of the experiment was prevented by a violent gust of wind, which tore the cloth in two places near the top before it ascended; however, it rose to the height of 1,440 feet, and, after remaining in the air about eight minutes, fell to the ground at the distance of 10,200 feet from the place of its setting out. The animals were not in the least hurt, though possibly the poor creatures, not knowing what it meant, may have felt rather nervous as they sailed upwards amid the acclamations of unnumbered thousands.

This successful ascent seemed to justify the boldest expectations. In the eyes of the sanguine Frenchmen who so often mistake their dreams for realities, the basket in which their national symbol, the Gallic cock, had ascended to the clouds, became a triumphal car ready to carry an enterprising traveller to the remotest corners of the earth; for, if brute animals, after soaring to mountain height, had been able safely to redescend to earth, surely man must be able to perform a similar flight, and to sail, a new Dædalus, high above the clouds.

Full of these thoughts, the ardent mind of Pilâtre de Rozier, a young and talented physicist, burned with eagerness to accomplish a journey never before attempted by man; and though since his time many thousand flights through the atmospheric regions have been successfully performed, and it now requires no very signal courage to ascend in the car of a balloon, yet the first aerial journey was undoubtedly an undertaking of uncommon boldness, and secures a lasting fame to Pilâtre's memory. To venture with very imperfect means upon a journey on which no one has ever ventured before, requires indeed a strength of mind far above the ordinary mark; and if Horace tells us that the breast of the first navigator must have been girded with triple steel, he surely would have still more forcibly struck his lyre in praise of the man who first soared into the mysterious regions of the clouds.

It cost the adventurous Pilâtre no little trouble to obtain the royal permission for his bold attempt. Louis XVI., whose kind heart, unfortunately for himself and his subjects, was but ill served by a weak and vacillating will, at first absolutely refused his consent, fearing lest the bold aeronaut should be lost in the unknown regions of meteoric space, or that the Montgolfière would take fire, and not only destroy the aerial navigator, but cause a conflagration on its descent. All he would allow was that two criminals condemned to death should make the experiment; but Pilâtre de Rozier was indignant at the idea that base malefactors should enjoy the glory of the first aerial ascent, and left no means untried to gain his end. The Duchess of Polignac, governess of the royal princes, who had great influence over the tractable spirit of the king, was his warm intercessor. The Marquis d'Arlandes, who had already made several small ascents with Pilâtre in a captive balloon, assured the king that there was no danger to be apprehended, and, as a proof of his conviction, offered to accompany the young aeronaut on his first *free* ascent. Pressed on all sides, vanquished by so many solicitations, the king finally gave way, as afterwards he yielded on many far more momentous occasions.

On November 21, 1783, Pilâtre and the Marquis d'Arlandes consequently ascended from the gardens of the Château de la Muette, near Paris, in a new and magnificent Montgolfière, measuring 70 feet in height, and 49 in diameter.

In spite of a heavy wind the balloon rose with great rapidity. When the bold travellers had reached a certain height and glided along over the heads of hundreds of thousands of spectators, they waved their hats as if to bid adieu to that vast multitude. Higher and higher they soared, until the two figures of the aeronauts vanished from sight, and the balloon itself grew smaller and smaller as it receded in the air. The towers of the church of Notre Dame were covered with spectators, and as the balloon flew between them and the sun they were enveloped in a novel kind of eclipse. The balloon had now attained a very considerable height, which increased or diminished accordingly as the aeronauts threw straw into the fire. It flew over the dome of the Invalides, and over the École Militaire, when a few rents in the covering of the machine attracted the notice of the Marquis d'Arlandes, who now thought it advisable to return again to the solid earth. The fire was no longer kept up, the balloon slowly descended, and after a short journey the bold adventurers alighted about seven miles from La Muette. The balloon itself had a better fate than the unfortunate 'Globe.' No flail belaboured it, no ignominious pitchfork was stuck into it, no horse dragged it across the fields; but, carefully packed upon a cart and under the guidance of Pilâtre, it was carried back again to the town from which it had so majestically risen.

Among the numerous noble and illustrious spectators who had assembled at the Château de la Muette to witness the grand sight of the first aerial voyage ever performed by man, was Dr. Franklin, at that time Minister Plenipotentiary from the United States to the Court of Versailles. Being asked what he thought of the future prospects of the invention, 'It is a newborn child,' he answered, diplomatically. His reply, while gratifying French vanity, might still be interpreted in a different sense, like one of the ancient Delphic oracles, and at all events saved him from the danger of appearing too sanguine a prophet.

Soon after this first ascent, Paris enjoyed the spectacle of a second aerial voyage, which Messrs. Robert and Professor Charles undertook in a balloon filled with inflammable gas. At this early stage of aerostation, the inventive genius of the Professor had already supplied the balloon with most of its requisites: the net spreading over the upper hemisphere and fastened to a hoop passing round its middle; the car or boat suspended by ropes in such a manner as to hang a few feet below its lower part; the valve for letting out the inflammable air in order to prevent the bursting of the machine, or to cause its descent, and the grapnel for securing a hold upon the ground on returning to the earth. A month had sufficed to imagine and accomplish all these ingenious contrivances, and on December 1, 1783, ten days after Pilâtre de Rozier and the Marquis d'Arlandes had opened the path to aerial navigation, the rival 'Charlière' successfully imitated their daring flight.

Thousands upon thousands were assembled in the Jardin des Tuileries, where the inflated but still captive balloon was impatiently waiting for its departure, when a royal order arrived forbidding the dangerous voyage to take place. The indignation of the public about to be disappointed of its expected pleasure may well be imagined. Charles immediately went to the Minister, Baron de Breteuil, and told him in energetic terms, that though the king was master of his life, he was not master of his honour. He had engaged to rise, and his word must be kept. Breteuil now gave the permission; but to prevent a new counter-order the balloon was liberated in all haste, and the aeronauts soared upwards into regions unattainable by royal authority.

'Nothing,' says Professor Charles, 'can equal the sensations of delight I felt on leaving the earth. Escaped from the dreadful torments of persecution and calumny,[1] I felt that I was giving a full answer to my enemies by raising myself above them. This pleasurable feeling was soon followed by a still livelier emotion—the admiration of the majestic spectacle that offered itself to our view: looking downwards, a sea of human heads; upwards, an unclouded sky; in the distance, an enchanting prospect.

'While we were gradually rising we waved our flags as a parting salute to our friends. Meanwhile I was constantly observing the barometer, and my companion making an inventory of our riches, for we had been amply provided with champagne, blankets and furs, as for a long journey. "Good," said I to him, "we shall not want for plenty of ballast." He began by throwing out a woollen blanket, which spread out majestically in the air, and came down somewhere near the dome of the Ascension Church.

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[1] Two parties had formed among the excitable Parisians—namely, the Montgolfieristes and the Charlistes, each of them praising its own favourite up to the skies, and casting odium and ridicule on his rival.

'The barometer now stood at 27 inches, from which I calculated our height to be about 600 yards. At this altitude I had promised to remain, and by throwing out ballast occasionally, as we found the machine descending by the escape of some of the inflammable air, we found it practicable to keep at pretty near the same distance from the earth during the rest of our voyage, the quicksilver fluctuating between 27 and 27·65 inches, and the thermometer between 53° and 57° the whole time.

'Sixty-five minutes after our departure, we heard, to our great pleasure, the firing of the cannon that was to inform us that the Parisian observers had lost sight of us. No longer obliged to devote all our attention to the maintenance of a horizontal direction, we were now at liberty to cast our eyes freely over the unbounded plain, with whose inhabitants we henceforward kept up a lively intercourse. From all sides they came running towards us; we heard their exclamations of joy, their congratulations. We called out to them "Vive le Roi!" and they all cordially joined us. We plainly heard them say, "My dear friends, are you not afraid?" "How delightful!" "We pray God that he may preserve you!" "Adieu, my friends!" I was moved to tears by this warm sympathy.

'We kept constantly waving our flags, and we perceived that these signs occasioned an increase of joy and confidence. Several times we allowed the balloon to descend tolerably low, so as to make ourselves better understood by our friendly interlocutors, and then we again rose, bidding them "Farewell."

'At length we landed in a great meadow which was enclosed with shrubs and some trees. On approaching these trees I feared their branches might strike against our boat. I threw out two pounds of ballast, and we flew over them like a horse clearing a hedge. We glided along very near to the ground, to all appearances as if we were driving in a sledge. The peasants ran after us to catch us, like children pursuing butterflies in a meadow.

'We alight. A crowd surrounds us. Nothing can surpass the good-natured *naïveté*, the open-hearted joy, the astonishment of the honest country people.

'A troop of horsemen comes galloping up to us. The Duke of Chartres, the Duke of Fitz-James, and Mr. Farrer, an English gentleman, who had followed us all the way from Paris.'

As the balloon still contained a great quantity of inflammable gas, Professor Charles determined to proceed alone on another voyage. M. Robert accordingly got out of the car, which was thus lightened by 130 pounds. Acquiring new buoyancy from the diminished weight it had to carry, the balloon now flew up like a rocket, so that in twenty minutes the adventurous Professor was almost 9,000 feet high, and entirely out of sight of terrestrial objects. At the moment of his parting from the ground the balloon had been rather flaccid, but it soon began to swell, and the inflammable air escaped from it in great quantity through the silken tube at its lower end. He also frequently drew the valve, that it might be the more freely emitted, and the balloon effectually prevented from bursting. The inflammable gas, being considerably warmer than the external air, diffused itself all round, and was felt like a warm atmosphere; but within ten minutes the thermometer indicated a change of temperature as great as that between the warmth of spring and the ordinary cold of winter. His fingers were benumbed by the cold, and he felt a violent pain in his right ear and jaw, which he ascribed to the dilatation of the air in those organs, as well as to the external air. The beauties of the prospect which he now enjoyed, however, made amends for these inconveniences. At his departure the sun was set in the valleys; but the height to which the Professor attained in the atmosphere rendered the flaming orb of the great luminary again visible, though only for a short time. By the light of the moon he perceived that the machine was revolving with him in the air, and he observed that there were contrary currents which drove him backwards. At last, recollecting his promise to return again to his friends in half an hour, he pulled the valve and accelerated his descent. When within 200 feet of the earth he threw out two or three pounds of ballast, which rendered the balloon again stationary; but shortly after he gently alighted in a field about three miles from the place whence he set out, though, by making allowance for all the deviations of his aerial flight, he supposed that he had gone through nine miles at least. By the calculation of M. de Meunier, he had ascended to a height of 10,500 feet, an elevation somewhat greater than that of Mount Etna. A small balloon, which had been sent off before the aeronauts set out on their voyage, took a direction contrary to that of the large one, having met with an opposite current of air, probably at a much greater altitude.

No wonder that after the successful issue of these first travels in the air all Europe began to build the most extravagant expectations on this new mode of locomotion. The tourist flew in thought over land and sea without troubling himself about passports and customs, turnpike tolls or post-horses. The naturalist paid visits to the eagle on the now no longer inaccessible mountain peak, or observed savages and wild beasts in perfect security from their attacks. The earth had no longer any secrets for the geographer. Central Africa lay open to his view, and an excursion to the North or the South Pole was a mere pleasure trip. The soldier flung down his missiles from on high on the defenceless enemy, or engaged in an aerial conflict with a hostile balloon. The demagogue, mocking the idle pursuit of the Government, stirred the enslaved nations to rebellion from his exalted rostrum, and set the world in a blaze without any danger to himself.

But while many go-ahead persons were full of eager hopes, others of a more conservative and desponding turn of mind had very different views of the future. How was the honest citizen to protect himself against housebreakers who, smiling contemptuously at his barred gates and windows, had but to remove a few tiles from his roof to invade his premises? and if a debtor did not choose to pay, how was the bailiff to catch him in his escape through the realms of air? Hostile armies could at any moment come dropping from the clouds, and, after horrid scenes of pillage and massacre, fly off again and renew their atrocities in some other quarter. In one word, all security of life and property was at an end; and though before the balloon could be brought to this anticipated perfection some *slight* difficulties had still to be overcome, no one doubted that post-chaises and packets were about to be numbered among the things of the past, and that society was on the point of undergoing a radical change.

Thus public attention was universally fixed upon aerial journeys; and as in the quiet and peaceful years which immediately preceded the French Revolution, no very exciting events took place on earth, people had full leisure to wander with their fancy in the skies.

The New World was not behind the old one in its eager adoption of the new art, for scarcely had the invention become known when aeronautical trials were made in America by Messrs. Rittenhouse and Hopkins, members of the Philosophical Academy of Philadelphia. The singularity of the plan upon which these experiments were contrived entitles them to notice. Instead of the one large vessel to contain the buoyant principle of the ascension, the machine employed by the American aeronauts consisted of several small balloons, in all amounting to no less than forty-seven, connected together and attached to the car, or *cage*, as they termed it, intended for the accommodation of those by whom it was to be freighted. After several preliminary experiments in which animals, and in one case a man, were let up to a certain height and drawn down again by means of a rope, Mr. James Wilcox, a carpenter, who had been induced for a small sum of money to hazard the attempt, entered the car (December 28, 1783), and, the ropes being severed, rose into the air, where he remained nearly ten minutes, when, perceiving himself rapidly approaching the Schuylkill river (which is there of a considerable breadth), he took the necessary measures to occasion his descent. For this purpose, according to his instructions, he made incisions in three of the balloons which were nearest to him with a knife, which not proving sufficient, he immediately opened three others. Seeing, however, that the machine did not descend, and fearing that he should not be able to clear the river, he hastily and incautiously opened five more, all upon one side, by which means the equilibrium of the machine was destroyed, and he reached the ground with so much violence that his wrist was dislocated in the fall.

Comparing the date of this ascent and that of Messrs. Charles and Robert upon the same principle, and taking into account the distance between the two localities, we find that the application of hydrogen gas to the purposes of aerostation was thus demonstrated in America without any communication with the continent of Europe.

We can have no better proof of the immense popularity which aerial navigation immediately attained after the first successful voyages had been made than the rapidly increasing number of its adepts. In 1783 but five persons were bold enough to soar aloft in a balloon, but in the following year their number had already increased to no less than fifty-two. As may easily be imagined, England, ever eager for daring exploits and exciting novelties, was not the last civilised country that offered its contingent to this bold phalanx. The credit of having accomplished the first aerial expedition ever executed in Great Britain has been generally ascribed to Signor Vincenzo Lunardi, a gentleman attached to the Neapolitan embassy in London, who ascended from the Royal Artillery Grounds, Moorfields, on September 15, 1784; but Mr. James Tytler, who made an ascent in a Montgolfière or fire-balloon from Comely Gardens, Edinburgh, on August 27, 1784, is in reality entitled to the triple distinction of having been the *first* native of Great Britain that ever navigated the skies, of having accomplished the *first* aerial voyage in these realms, and (with the exception of Mr. Sneath[1]) the *only one* upon the dangerous principle of the original inventor.

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[1] Mr. Sneath ascended from Bleak Hill, near Mansfield, on the night of May 24, 1837, in a fire-balloon of his own construction. After remaining in the air for two hours, the balloon began to descend, and at eleven the grapnel took effect on a hedge. Apprehensive of the escape of the balloon in case he should quit it, and afraid to allow the fire to abate, lest, no longer able to support itself, it might fall upon the furnace and be consumed, he was fain to remain in the car until half-past four in the following morning, when some workmen, happening to pass by, came to his assistance, and enabled him to quit his irksome situation.

The largest balloon that ever navigated the air ascended at Lyons, January 19, 1784. This monstrous aerostat, named ‘Le Flesselles,’ in honour of the lady of the governor of the province, measured when duly inflated 130 feet in height and 105 in breadth, was capable of containing 540,000 cubic feet of air, and when loaded for the ascent supported with ease seven persons and ballast to the amount of 3,200 pounds, independent of its own considerable weight, including a furnace 20 feet in diameter, with its proportionate store of fuel made up into faggots of wood and straw. The names of those who shared the honour of this expedition were Joseph Montgolfier, who hoped by its magnitude entirely to eclipse the ‘Charlière,’ Pilâtre de Rozier, le Comte de Laurencin, le Marquis de Dampierre, le Comte d’Anglefort, le Prince de Ligne, and a young man named Fontaine. The frantic enthusiasm of the crowd when the colossus slowly and triumphantly ascended was indescribable. More than 100,000 spectators shouting, clapping their hands, waving their handkerchiefs, or throwing their hats into the air, afforded a scene such as may be supposed to have taken place in the Colosseum when all its vast assembly applauded the death-stroke of some favourite gladiator, or the spring of a lion upon some doomed victim.

The travellers remarked that on attaining a height of 3,000 feet they required far less fuel than near the earth’s surface to keep the balloon afloat, and the hopes of being able to continue their journey till nightfall filled them with the highest spirits. To rise still more they increased their fire; but as is often the case, when too confident of success we overstep the bounds of prudence, they had now to suffer the penalty of having forgotten the wise maxim ‘to leave well alone;’ for the sudden distension of the balloon by a too rapid influx of heated air caused a rent in its cover of about four feet in length, and instead of soaring upwards they fell rather ungently at the short distance of only 1,200 feet from their starting point, scarce a quarter of an hour after they had left it.

In spite, however, of this abrupt termination of their aerial career, their return to Lyons was a triumphal procession. The opera of ‘Iphigenia in Aulis’ was to be performed at the theatre the same evening, and the house was crowded in the hopes of seeing the heroes of the day. The play had already begun when M. and Mdme. de Flesselles entered their box, accompanied by Messrs. Pilâtre de Rozier, Montgolfier, and their noble companions. The enthusiasm of the public, which may be more easily imagined than described, rose to boiling heat when the actor who performed the part of Agamemnon stepped forward with crowns of laurel which Mdme. de Flesselles distributed among the illustrious aeronauts; Pilâtre de Rozier modestly placing that which he received on the head of Montgolfier. Who would then have thought that but a few years after, exile or the guillotine would be the fate of most of those to whom this brilliant ovation was tendered?

The same year, 1784, witnessed the successful aerial journey of Mdme. Thible, the first female aeronaut, who ascended from Lyons in a Montgolfière on June 4, in the presence of the Court, and of King Gustavus of Sweden (assassinated in 1792 by Ankerstrom), then travelling under the name of Count Haga. Mdme. Thible is perhaps the only woman who ever ascended in a fire-balloon.

Among the aeronauts of 1784 the Duke of Chartres deserves to be mentioned. This prince, who afterwards, under the name of Philippe Égalité, played so inglorious a part in the French Revolution, ascended from the park of St. Cloud, July 15, 1784, in company with Messrs. Charles and Robert, in a balloon filled with hydrogen gas. His aerial excursion came, however, to a premature conclusion, in consequence of the accidental dislodgement of a smaller balloon, filled with atmospheric air, which had been disposed within the body of the aerostat to regulate its equilibrium, and which by its fall closed the aperture at its mouth. The danger of the balloon bursting as it rose and expanded in the warm sunshine was imminent, when the duke, seizing a flagstaff, made a large rent with its point in the side of the distended globe, and thus allowed the gas to escape. They now fell with alarming velocity, and with difficulty escaped being immersed in one of the ponds of the park of Meudon, where they alighted without any further accident.

The whole expedition had scarcely lasted a few minutes, and, in spite of the presence of mind the duke had shown, he incurred the ridicule of his numerous enemies, who, alluding to the sea-fight off Ushant, declared that he had made the three elements—land, water, and air—witnesses of his natural cowardice.[1]

Early in the year 1786 we find the balloon rousing the curiosity even of the apathetic Turks. The circumstances of an aerial journey performed at that time at Constantinople, by a Persian physician and two Bostangis, or officers belonging to the seraglio, are extremely interesting, considering the age in which it took place and the country in which it was accomplished. The bold Mussulmen ascended from the court of the sultan's palace, in the presence, and to the great delight of, the ladies of the harem. Traversing the sea which divides the European from the Asiatic continent, after an agreeable and prosperous voyage of four hours and a half, they descended about thirty leagues from the coast, near the castle of Bursia, the residence of a pacha, by whom they were nobly and hospitably entertained. Upon their return they were received with all the honours which an admiring public could bestow; and the balloon itself, as a memorial of the exploit, was ordered by the sultan to be suspended in the Church of St. Sophia.

Left to the caprice of the winds, the balloon had hitherto sailed at random through the atmosphere; but as the mind of man, never satisfied with the conquests it achieves, is constantly striving onwards from discovery to discovery, the idea soon arose how much its importance would be increased if means could be found to direct its course and regulate its motions. Mr. Blanchard, a gentleman who had for several years before amused himself with endeavours to fly by mechanical means, and had necessarily failed in his attempts, now thought of adding the wings of his former machine to a balloon, and made no doubt that it would thus be in his power to direct himself through the air at pleasure. He fixed upon March 2, 1784, for the first public exhibition of his aerial steersmanship; but in the execution of this design he was disappointed through the impetuosity of a young man, who, unable to obtain permission to share in the honours of the projected experiment, sought to wreak his vengeance upon the balloon, running his sword through the silk and otherwise damaging the machinery by which it was to have been propelled; so that Blanchard, having hastily repaired the injuries done to his balloon, ascended without being able to make use of it. A succeeding attempt, however, showed that all the strength which Blanchard could apply to his machinery was insufficient to counteract the impression of the wind in any degree; and Messrs. Charles and Robert, who on their second aerial journey gave their balloon an horizontally elongated form, and provided the car with five large wings or oars, were equally unsuccessful; for, however vigorously they rowed, even the moderate wind which blew at the time mocked their efforts to overcome its power.

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[1] The following epigram was made on the occasion:—

Mais quel soudain revers, hélas!
Ne vois-je pas mon prince en bas?
Comme il est fait, comme il se pâme,
On dirait qu'il va rendre l'âme—
L'âme—oh! qu'il n'est pas dans ce cas!
Peut-on rendre ce qu'on n'a pas?

Blanchard, having thus incurred ridicule where he had hoped to achieve fame, soon after retrieved his defeat by his aerial voyage across the straits of Dover. This daring expedition, in which he was accompanied by Dr. Jeffries, an American gentleman, took place on January 7, 1785, on a clear, frosty morning, with a scarcely perceptible wind blowing from England towards France. The balloon ascended at one o'clock from the classical ground of Shakspeare's Cliff, only a few feet from the precipice so beautifully described in 'King Lear.' As it was scarcely large enough to sustain the weight of two persons, and, owing to the condensation which ensued while over the sea, had a constant tendency to fall, the bold aeronauts were obliged to throw out all their ballast soon after starting, except three bags of ten pounds each, when they at last rose gently, though making little way as the wind was very light.

At a quarter after one o'clock the barometer, which on the cliff stood at 29·7 inches, had fallen to 27·3, and the weather proved fine and warm. They had now a most beautiful prospect of the south coast of England, and were able to count thirty-seven villages upon it. After passing over several vessels, they found that the balloon at 50 minutes after one was descending, on which they threw out a sack and a half of ballast; but as they saw that it still descended, and with much greater velocity than before, they now parted with all the ballast they had left. This still proving ineffectual, they next flung away a parcel of books they carried along with them, thus causing the balloon to ascend, when they were about midway betwixt France and England. At a quarter past two, finding themselves again descending, they sacrificed the remainder of their books, and ten minutes afterwards they had a most enchanting view of the French coast, which seemed rising out of the sea to welcome them. Still, however, the machine descended, and as their library was now exhausted, they were obliged to cast out their provisions, and everything they could possibly spare. 'We threw away,' says Dr. Jeffries, 'our only bottle, which in the descent cast out a steam-like smoke with a rushing noise, and when it struck the water we heard and felt the shock very perceptibly in our car and balloon.'

But still the descent continued; and they were in imminent danger of terminating among the finny denizens of the deep the voyage they had begun like the winged tenants of the air. In this extremity they threw out their anchors and cords, their hats and coats, and at last fastened themselves to the ropework of the car, which they intended to cut away as their last resource. They had now the satisfaction, however, to find that they were rising, and that the wind was carrying them rapidly towards the coast of France, which kept constantly growing and expanding in beauty as they advanced. Elated by the proud feeling of being the first who had ever sailed across the Channel upon the waves of the atmosphere, they little felt the inconvenience of travelling in their shirt-sleeves in winter; and thus they flew over the high lands between Cape Blanc and Calais to the forest of Guienne, where Dr. Jeffries caught hold of the branch of a tree and forced the machine to stop. The valve-rope was pulled, the gas escaped with a hissing noise, and shortly after the aeronauts once more set foot upon the earth. It would be difficult to describe the enthusiasm with which Blanchard was greeted by his excitable countrymen. The town council of Calais presented him with the freedom of the city in a golden box, and decided on erecting a marble monument on the spot where he had landed. A few days after the fortunate aeronaut was ordered to appear before the king, who granted him a pension for life of 1,200 livres. The queen, who was playing at cards at his reception, graciously ordered the considerable sum which she gained to be presented to him. In one word, nothing was wanting to the triumph of Blanchard, not even the envy of his enemies, who gave him the nickname of the new Don Quixote of La Mancha (la Manche, or the sleeve, being, as is well known, the French name of the Channel).

BLANCHARD'S DESCENT.

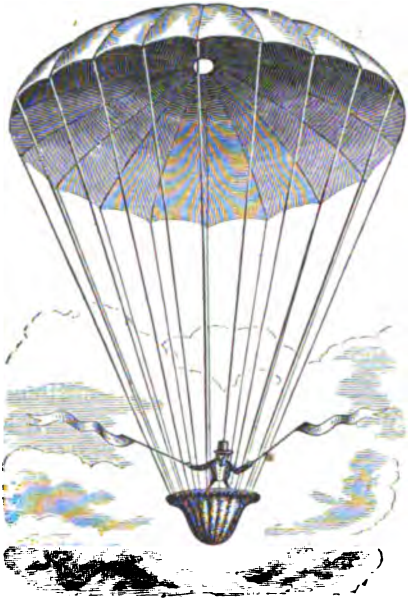
Unfortunately, the success of this bold flight across the sea gave rise to one of the most tragic events in the annals of aerostation; for as soon as Pilâtre de Rozier heard of Blanchard's voyage, he immediately resolved to imitate his example by soaring over the Channel in the opposite direction, from France to England. On June 15, 1785, he accordingly ascended at Boulogne, in company with a young gentleman named Romain; but, by a sad mischance, the arrangements which he adopted to insure his success were the causes of his failure and destruction. In order to counteract the fluctuations consequent upon all aerial excursions under the ordinary circumstances, and obtain the power of increasing or diminishing the weight of his apparatus at will, without the usual expenditure of gas and ballast, he had conceived the idea of uniting in one the two systems of Montgolfier and Charles, and accordingly affixed to the hydrogen gas balloon, by which the principal part of the weight was to be borne, a small fire-balloon, by acting upon which he expected to be able to alter his specific gravity as occasion might require. The theory was correct, the error lay in the application. Distended in the course of

TRAGICAL END OF PILÂTRE DE ROZIER.

its elevation, the inflammable contents of the larger sphere soon filled the vacant portions of the silk, and, pouring down the tube which formed the neck of the balloon, speedily reached the furnace, which was placed at its lower extremity, and became ignited. The whole apparatus was consumed in the air, and the two unfortunate travellers fell down upon the rocks which bound the shores of the sea between Calais and Boulogne. When the horror-struck witnesses of the catastrophe hurried to the spot, M. Romain still showed some signs of life; but Pilâtre de Rozier had ceased to breathe, and all his bones were broken. Thus the first aeronaut was also the first victim of aerial navigation. By a strange irony of fate he came to his untimely end on the very spot where Blanchard had triumphantly landed.

Pilâtre's tragical death probably gave the first impulse to the use of the parachute—an apparatus resembling a gigantic umbrella, which, by the resistance of the air, spreads out as it falls, and thus counteracts the danger of a too rapid descent. The aeronaut seated in a small car suspended by ropes attached to the circumference of the parachute prevents its being overturned by maintaining the centre of gravity far below.

The principle of the parachute is so extremely simple, that the idea must no doubt have occurred to many persons who saw the flying squirrel, or other animals similarly provided with expansible membranes, sailing obliquely downwards from one tree to another. Even in the remote regions of Siam, Father Loubère, in his curious account of that country published more than two centuries since, mentions a person who was wont to divert the court by his exploits in descending from great heights through the aid of such an instrument—a practice which was probably not confined to Siam alone of all the countries of the East. In Europe, however, no notice appears of any attempt to use an apparatus of the kind as a preventive against a too rapid descent through the atmosphere, till the year 1783, when a gentleman of the name of Le Normand first practically demonstrated its efficiency by letting himself down from the windows of a high edifice at Lyons. The views of M. Le Normand with regard to its employment were, however, limited to its adoption as a means of escape from fire; nor was it till some time after that the ingenious and speculative Blanchard first conceived the idea of applying it as a useful adjunct to the balloon. This design he endeavoured to put into execution at Basle, in the year 1793, having first satisfied himself of its security by letting down dogs and other animals from various heights. In attempting to repeat the experiment upon himself, however, he was less fortunate; for, owing to some mismanagement, his machinery failed in its effect, and, coming to the ground with too great rapidity, his leg was broken in the fall.



PARACHUTE.

To André Jacques Garnerin is due the honour of having been the first aeronaut who ever successfully descended from a balloon by the aid of a parachute. This he accomplished in an ascent from Paris on October 21, 1797, in the presence of an immense concourse of people who had assembled to witness the experiment. At the height of about 2,000 feet the act of separation was effected, and the balloon and parachute immediately started off in opposite directions. The former, however, was soon lost sight of, all eyes being involuntarily directed to the descending mass, and all interest centred in its bold occupant. For a few seconds the consummation of his fate seemed to be all but inevitable; the parachute obstinately maintaining its collapsed position. All of a sudden, however, it expanded, and the downward progress of the adventurer appeared at once to have been arrested as by an unseen hand.

The fears of the spectators now began to assume another aspect, for the moment the parachute had expanded, the car of the aeronaut, which was suspended about twenty feet below it, shot out on one side with an impetus that almost brought it upon a level with the rest of the apparatus, and for an instant seemed to threaten his being hurled from his seat. Recovering itself, however, by its force of gravitation, it soon redescended, and, swinging round to the opposite quarter, commenced a series of violent oscillations which, for a considerable time, seemed to render the issue of the experiment a matter of much uncertainty. As Garnerin approached the earth, however, these gradually became fainter, and, although they never entirely disappeared, soon ceased to excite the immediate apprehension of his friends. At length, in about twelve minutes, he reached the ground, and was released from the parachute, without having experienced any injury. The dangerous oscillations of the parachute have since been obviated, by leaving an opening at the top of the umbrella, which, by allowing the air to escape at the point opposite to its centre of gravity, maintains its equilibrium.

Garnerin's example has often been successfully imitated for the purposes of public exhibition, and in one case it has proved the means of saving an aeronaut's life. On July 24, 1804, Fordaki Kuparento ascended from Warsaw in a fire-balloon; when at a considerable altitude in the sky, his balloon became ignited. Being provided, however, with a parachute, he descended in safety.

Meanwhile, the balloon mania had been spreading more and more throughout Europe. Everybody was longing to witness an aeronautic ascent, if not to ascend himself; and thus we soon find professional aeronauts exhibiting the new art from town to town and from land to land, and everywhere reaping a golden harvest. Among these the celebrated Blanchard distinguished himself by his ridiculous vanity, which prompted him to assume the title of 'aeronaut of both hemispheres, honorary citizen of Calais, and of the capitals of both worlds;' as well as the number of his ascents, which amounted to more than sixty.

In spite of his repeated challenges to fate, Blanchard died like an ordinary mortal by a stroke of apoplexy in 1809, while his wife, who after his death continued his lucrative profession, perished in a more poetical manner by falling from the clouds. The unfortunate woman had well-nigh perished once before during an ascent at Nantes in 1817. She then fell into a swamp; but, as the balloon remained hanging in the branches of a tree, she was able to maintain herself above water until assistance could be procured. Her narrow escape from death, which should have checked her rashness, added, however, but two short years to her life. On July 6, 1819, she ascended from the Tivoli Gardens in Paris, with the intention of heightening the interest of an ordinary balloon voyage by exhibiting herself amidst a blaze of rockets and Bengal lights. This playing with fire near a balloon filled with inflammable gas was to meet with a dreadful punishment. The balloon took fire, and in her fall Madame Blanchard was dashed to pieces on the parapet of the house No. 16 Rue de Provence, Faubourg Montmartre.

Garnerin was Blanchard's chief rival in aeronautic fame. His wife, who often accompanied him in his ascents, had already distinguished herself before her marriage by venturing down in a parachute at St. Petersburg, from a height of 3,000 feet; a mode of descent she afterwards frequently adopted. Eye-witnesses relate the terrible impression made on the spectators when they saw her shoot down like a rocket with her still closed parachute; but the protecting umbrella always unfolded in time to let her down safely on the earth.

On August 20, 1809, the inhabitants of Aix-la-Chapelle were astonished to see a small black speck in the sky, which gradually increasing in size, finally assumed the form of a stately balloon, and descended in their neighbourhood. It belonged to Garnerin, who had ascended from Paris the night before to descend at noon in the old capital of Charlemagne. This was the longest journey that had ever been performed by an aeronaut, although empty balloons had already taken a much wider flight. Thus the colossal aerostatic machine, girdled with a crown of 3,000 coloured lamps, which ascended at Paris on the day of Napoleon's coronation (December 16, 1804), descended near Rome twenty-two hours later. The new Cæsar, highly pleased at the remarkable manner in which his elevation had been announced to the capital of the ancient Cæsars, and taking it probably for a lucky omen, made a present of the balloon to the pope, who ordered it to be preserved with a fitting inscription among the curiosities of the Vatican.

A tragical interest is attached to the memory of Count Zambeccari of Bologna, one of the most deservedly celebrated of those whose names adorn the annals of aerostation. In the very outset of the art of which he afterwards became the victim, we find this nobleman's name coupled with the ascent of a small balloon ten feet in diameter, which he made and launched in London on November 25, 1783, and which is generally mentioned as the first aeronautical experiment ever instituted in this country.[1] Here likewise he made his first ascent, on March 23, 1785, in company with Admiral Sir Edward Vernon, upon which occasion, after having risen to a considerable height, they descended at Horsham in Sussex, a distance of thirty-five miles, in something less than an hour.

Shortly after this Zambeccari seems to have entered the Russian service, for in 1787 he was made prisoner by the Turks as a Russian seaman, and confined for three years in the bagnio at Constantinople, where he had full leisure to meditate on the possible improvement of aerial navigation, a pursuit to which, from the beginning, he had devoted himself with a zeal and ingenuity which never abated until they were finally quenched in the fatal enterprise which ended his career. By the invention of a large spirit-lamp with twenty-four openings, each of them provided with a lid, which could be quickly opened or closed, he hoped to have found the means of regulating the flight of a moderately filled gas-balloon, and of causing it to rise or fall or to remain at the same height, without any loss of gas or the throwing out of ballast.

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[1] The precedence ascribed to this event can, however, have been but of very few hours at the utmost, for on the same day another balloon, which had been manufactured by an ingenious Prussian, M. Argeue, was launched from the hands of the king himself at Windsor, for the entertainment of his royal consort. See 'Scots Magazine,' date as above.

In the year 1803 we find him at Bologna, when, eager to try his experiment, he ascended in company with Count Andreoli and Dr. Grassetti. In consequence of great delays in the filling of the balloon, the ascent did not take place before midnight. The aeronauts rose slowly in the air and remained a long while over the town. Suddenly, however, they were seen to move with great rapidity, and a south-westerly wind soon carried them out of sight. The spirit-lamp for some reason or other was not used.

'We descended,' says Zambeccari,[1] 'in a thick stratum of cloud, and when we had traversed it Andreoli heard a scarcely perceptible noise, which he soon recognised as the distant breaking of the waves on the coast. He immediately communicated to me this terrible intelligence. I listened and persuaded myself of its truth. The noise of the breakers grew more and more distinct, and I soon distinguished the surface of the violently agitated Adriatic. I immediately seized a sack with ballast, but at the same moment the gallery fell into the sea and we were all in the water. In the first alarm we threw out everything that could lighten the aerostat—our ballast, all our instruments, part of our clothes, our money, and, as the balloon still remained in the water, the spirit-lamp, and all we could possibly detach from the machine. Suddenly, it disengaged itself with considerable violence, and, having so much less weight to carry, rose to an immense altitude, so that our loudest speaking seemed to come quite feebly from a distance. I felt very sick, Grassetti bled from the nose, and we both breathed with difficulty. As we had thus been carried aloft in wet clothes, these were soon covered with a crust of ice. We remained about half an hour in the high atmospherical regions, when the machine again began to descend and gently deposited us on the surface of the water. It was somewhat later than three o'clock. How far from land the balloon dropped into the sea, it is impossible to determine. The night was too dark, the sea too turbulent, and we ourselves utterly incapable of making observations. We may have been perhaps in the middle of the Adriatic, in the direction of Rimini. In spite of our gentle descent, the gallery was totally immersed; we were plunged up to our middles in water, and were often completely overflooded by the waves. As the balloon was now only half filled, it caught the wind like a sail, and thus we were dragged along for several hours through the stormy waves. At break of day we found ourselves about four Italian miles from the coast of Pesaro, which we recognised. We already indulged the hope of landing there, when suddenly a sharp land-wind again drove us out into the open sea. It was now full daylight, and we saw all around nothing but water, the sky, and an inevitable death. We indeed met several ships, but as soon as they saw the balloon approach they were alarmed, and steered far away from us. We had thus no hope left but to be able to reach the opposite coast of Dalmatia. This hope was, of course, very weak, and most probably we should finally have been swallowed by the waves, had not a skipper appeared to save us, who, more enlightened than those who had fled, recognised the balloon as such, and immediately sent out a boat for our rescue. The sailors fastened a strong rope to the gallery, and with great difficulty dragged us towards them into the boat, as we were totally helpless. The machine, being thus once more considerably lightened, again strove to ascend, and the sailors in vain exerted all their strength to drag it after them. The boat was violently shaken; they themselves were in danger; they therefore hastened to cut the rope, and immediately the balloon rose with incredible rapidity into the clouds, where it was soon lost to sight. It was eight o'clock when we came on board the ship; Grassetti was nearly dead, and scarcely gave any signs of life. My hands were maimed; cold, hunger, and alarm had completely exhausted me. The excellent skipper did all he could to restore us. He brought us safely into the port of Vereda, whence we were conveyed to Pola, where we met a hospitable reception.'

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[1] See Kotzebue, 'Erinnerungen von einer Reise aus Liefland nach Rom und Neapel,' vol. iii. p. 358.

After so perilous a journey, which moreover cost him a considerable part of his property, it might have been supposed that our gallant adventurer would have relinquished all future travels in the air; but Count Zambeccari, in no way intimidated, persevered in his intention to try, under more favourable auspices, the spirit-lamp with which he hoped to mark a new era in aerostatics. We consequently see him once more ascending at Bologna in the following year, amid the roar of cannons and the applause of many thousand spectators. This time it seemed as if fire and water had conspired for his destruction, for as he was upon the point of landing with his trusty companion Andreoli, about six miles from the town, the balloon inclined to one side by the throwing out of the grapnel, so that the burning spirits with which his lamp was filled ran over. The clothes of the aeronauts, their instruments, the ropes, the gallery, were all in flames. Zambeccari emptied a bottle of water over his head, and succeeded in extinguishing the fire, at least on his own person. Andreoli, in order to save himself from the flames, slid down the rope, and fell very ungently upon the ground, while the balloon, having thus lost part of its weight, once more ascended with incredible rapidity. As long as the spectators could follow Zambeccari with their eyes he was seen busy extinguishing or casting away the burning objects with which he was surrounded. But soon the balloon, which rose to an enormous height, was lost to sight, and driven to the north-west. The whole catastrophe was the work of only a few minutes.

In spite of this desperate situation Zambeccari did not lose courage. He had ascended so high that, to use his own expression, he looked down upon the clouds as into an abyss. His hands, already weakened by his last year's ascent, suffered terribly from the cold. A current of air now transported the balloon rapidly over the Adriatic Sea, into which it gradually descended, about five miles from the coast of Italy. A part of the gallery sank into the water, and Zambeccari himself was immersed up to his waist. He cast an anxious glance around, but nothing was to be seen but sea and sky. His courage, however, did not fail him; he was convinced he could not be far from the coast, and that the wind, which blew over the water in an opposite direction to that which had prevailed in the air, would soon convey him to the shore. But after waiting a long time, and still seeing no coast appear above the horizon, he at length discovered that the grapnel had fastened to the bottom of the sea, and prevented the balloon from advancing. He immediately saw the necessity of cutting the rope; but how was this to be done? He had no implements, his right hand was frozen, his left maimed. But here again necessity showed herself as the mother of invention. He broke the lens of a telescope, and, holding the largest piece of glass between his teeth, began to file at the rope, which, being soaked through, easily gave way. The wind now drove the balloon towards the coast of Italy, and after having thus sailed for a couple of miles, he met seven fishing-boats. The first four, when they saw this strange-looking machine upon the water, were seized with a panic-terror, and immediately rowed away as fast as they could. Fortunately the other three boats were less timorous. Their approach, however, was extremely slow and cautious, but, as soon as they distinguished the balloon, one of them spread his sail and rapidly approached it. Antonio Malta, of Chioggia, was the master of the bark which had the honour of preserving Zambeccari from a watery grave. It was high time; he had already been four hours immersed; the car was sinking deeper and deeper, and he was nearly up to his neck in water.

The good fishermen did their best, for his preservation was attended not only with difficulty, but also with danger. They vainly tried to retain the balloon, which, as soon as it was unloaded, rose again with great impetuosity, and went over to the Turks. In spite of the dreadful fatigue he had undergone, the strong mind of Zambeccari enabled him to bear up against his sufferings. He spent a tolerably easy night on board of the bark. On the following morning he reached Magnavacca, and travelled thence to Bologna, where he was enthusiastically received. Unfortunately the bad state of his health cast a shade over the joy occasioned by his preservation. It was feared that his right hand must be amputated; he, however, lost only two fingers.

The spirit-lamp, which played so disastrous a part in this second voyage, was unfortunately destined to be the cause of his death; for, on attempting to descend after a voyage he made from Bologna, on September 21, 1812, in a balloon constructed upon the same pernicious principle, the grapnel caught for an instant in the branches of a tree, and, by the shock which it produced, overturned the lamp, whose contents speedily set fire to the whole machine. Unable to resist the rapid encroachment of the devouring element, Zambeccari and his companion, Signor Bonaga, sprang from the car as a last resource, in spite of their considerable elevation from the ground. Zambeccari died on the following morning, at the age of fifty; Bonaga, more fortunate, though fearfully injured, escaped with his life.

A few months before this fatal catastrophe, the annals of aerostation had registered another victim to the bold attempt of using fire as means of keeping a balloon afloat in the air.

Herr Bittorff, a German aeronaut, had frequently ascended in a fire-balloon with signal success, but he also had ultimately to suffer for his temerity. On the occasion of his death, which took place at Mannheim on July 17, 1812, he had risen for the thirtieth time in a balloon of this description, and had reached a very considerable elevation, when it took fire, and he was precipitated upon the roofs of some buildings adjoining the outskirts of the town.

CHAPTER XXXIV.

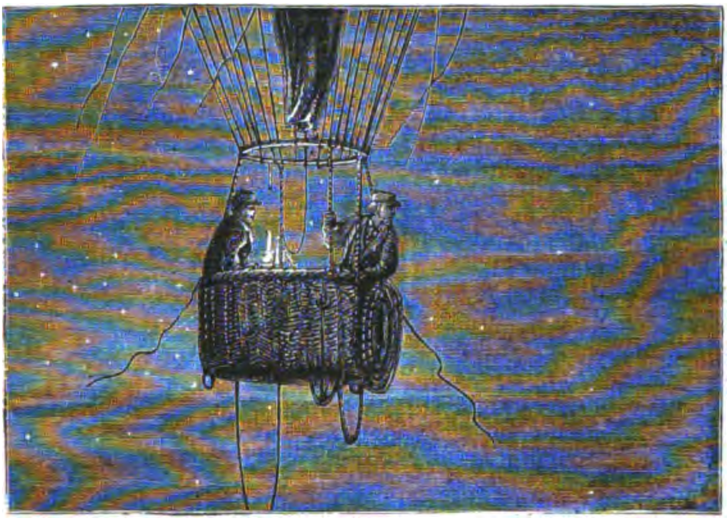
THE PLEASURES AND PERILS OF AERIAL NAVIGATION.

Gorgeous Imagery of the Clouds—Bird's-eye View of London—A New Leaf of Nature—Baron Munchausen in the Clouds—Delays before Ascending—Perilous Ascents of Green and Arban—Wilber and Knapp—Bursting of a Balloon—Difficulties of Landing—Windham Sadler—A Diabolical Villany—Trailing of a Balloon—The Balloon a Plaything of the Winds—Nadar's Disastrous Journey in the 'Géant'— The 'Swallow'—Fright of Animals—A Winged Monster.

THE discovery of the balloon has opened to man the portals of a new and wonderful world, and enabled him to enjoy scenes of beauty hidden from the gaze of all preceding generations.

The mountaineer requires many hours to reach the term of his fatiguing ascent—the high Alpine peak—where at length a magnificent prospect—which, however, can be seen but from one spot, and consequently varies but little in its features—rewards his toil. But in a few minutes the aeronaut soars upwards to the empyrean, where, without the least bodily exertion, the grandest cloud-pictures, the most splendid effects of light, unknown to all that cling to the surface of the earth, enchant his eye with a constant succession of new and ever-shifting scenes as he is wafted along. For him the sun sets with his richest tints; for him the dawn and the twilight exhaust all the magic of their roseate and purple hues; for him the moon shines with redoubled brilliancy and the stars sparkle with unwonted lustre from the dark background of the skies.

It is indeed impossible to conceive a situation from which the beauties of a landscape can be seen to greater advantage or with more singular effect than that wherein the aerial traveller is placed while sailing through the atmosphere at a moderate distance from the earth beneath. The novel aspect under which a vertical view presents all objects to the sight, his isolated position, and, above all, the exquisite, imperceptible motion of the balloon, which bears him softly along as if on spiritual wings, are all effects perceivable under no other circumstances. At a greater height, all individual objects are lost in the immensity of the prospect, or merely appear as the diminutive objects of a Lilliputian world; but as the balloon approaches the ground and skims along its surface, they gradually assume their real dimensions. The forests and parks, no longer an undistinguishable mass of verdure, separate into individual trees; the houses, roads, fields, and rivers now also begin to display themselves distinctly; and, most interesting of all, the living forms of nature, altogether invisible from the higher regions, begin to mingle in the scene, and give life and expression to the landscape.



A GLANCE INTO SPACE BY NIGHT.

At a height where all terrestrial objects become dim and indistinct, the gorgeous imagery of the clouds reveals new splendours to the aeronaut's enchanted gaze.

'To appreciate all the beauty of cloud scenery,' says Mr. Glaisher, 'an aerial voyage must be made on an autumn morning before sunrise, when the atmosphere is charged with the vapours of night. It was towards the end of August, and we left the earth at half-past four A.M. The morning was dull, warm, and misty, and the sky was covered with cloud. The balloon bore us gently upward, making the first 1,000 feet in eight minutes; all below was thick mist, veiling the surface of the earth. At 5,000 feet we just emerged above the clouds. They, however, presently again formed all round and above the car, closing everything from view, excepting only a line, bright as silver, which indicated the east. We were in a basin of cloud, whose sides extended far above us all round. We slowly rose, and when we reached its boundary the sun rose, flooding with light the whole extent of cloudland beyond, which glistened like a golden lake under his beams. The scene all round possessed a grandeur far exceeding sunrise as viewed from the earth. Grouped around the car, both above and below, there were clouds of Alpine character sloping to their bases in glistening light or towering upwards in sheets of shining vapour, which added the charm of contrast to the splendid tints of sunrise. The clouds spread around us like an ocean, and,

BALLOON SAILING THROUGH SKY AT SUNRISE.

continually changing their forms, suddenly gathered themselves into mountain-heaps, and closed all round us, hiding the sun in neutral-tinted gloom. The earth was visible through breaks, and the early morning mists were seen creeping upon its surface as the daylight gathered strength.'

Fancy the aeronaut ascending amidst the thickest fog which can possibly obscure the streets of London; but, as he rises, the mist dissolves, and, emerging from darkness, he soon revels in all the glories of sunset, rendered still more beautiful by the contrast with the gloom below.

'We are 9,800 feet high,' says M. Tissandier. 'The clouds illuminated by the sun are of a strange tint; they are of a violet-rose colour, and spread in elegant forms along our horizon. But this is only the prelude to the magnificent spectacle of sunset which is approaching. Soon the sun disappears behind a curtain of cloud that hides its magic splendour, but from behind this dark veil of purple a thousand golden rays shoot forth and dazzle the eye. They all appear to emanate from a central point, which, though invisible, can easily be traced to its proper place. No poet has ever dreamed of such a brilliantly radiating spectacle, nor imagined such dazzling lines of fire. We rise to an altitude of 12,500 feet in the midst of this splendour, whilst absolute repose reigns throughout Nature. What a sublime harmony of colours, light, and silence!

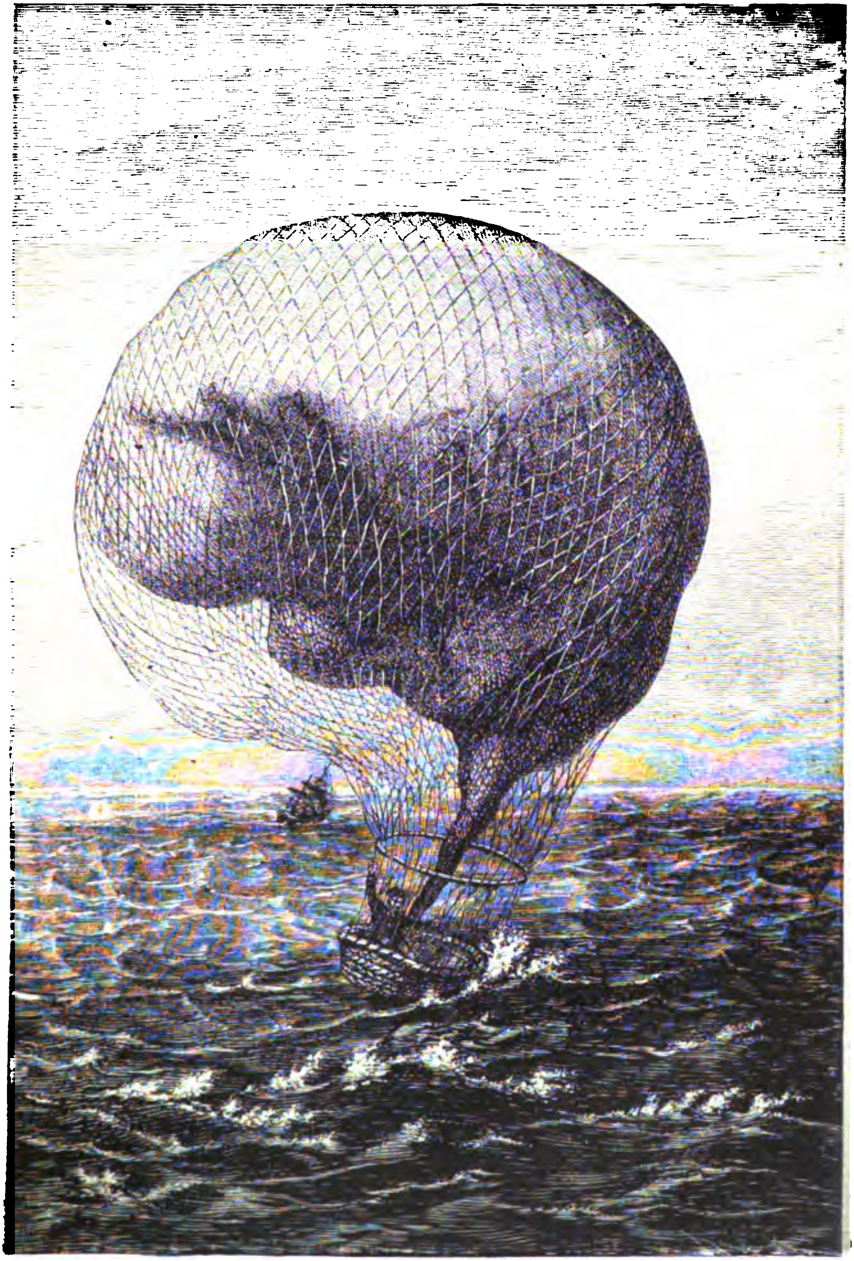
'Thus suspended in the infinite realms of space, we cannot sufficiently admire the last glorious rays of the setting sun, and the splendour of the clouds as they receive its celestial illumination. It is with a sort of ecstasy that we turn our eyes towards the earth, now only visible through the semi-transparent mist, masked as it were by a veil of rosy muslin. The river Marne winds across the country, and a long blue ribbon of vapour exhales from its blue waters. Farther on is an aqueduct, the only vestige of human art in the whole glorious landscape. Whilst the sun sinks slowly behind the western horizon, the more vivid colours die out, and are succeeded by rich purple tints fringing the borders of the vapour mountains, whilst the sky above is dark indigo blue, and the earth puts on the tint of a pale emerald. The Marne has a rosy hue like that of the petals of newly-budded flowers, and our balloon follows its silent course amidst all these marvellous displays of colour, belonging neither to the earth nor to the sky, but soaring between these two brilliantly illuminated hemispheres.'

But a spectacle of a more vivid interest than that which inanimate cloud-land, however beautiful, can afford, reveals itself to the aeronaut, when from his lofty seat he looks down upon a giant city like London. One of the most striking effects is the diminutive size to which all objects are dwindled. 'Railway trains,' says Mr. Glaisher, describing one of these bird's-eye views of the great metropolis and its environs, 'were like creeping things, caterpillar-like, and the steam like a narrow line of serpentine mist. All the docks were mapped out, and every object of moderate size was clearly seen with the naked eye. Taking a grand view of the whole visible area beneath, I was struck with its great regularity: all was dwarfed to one plane; it seemed too flat, too even, apparently artificial. The effect of the river scenery in this respect was remarkable; the ships, visible even beyond the Medway, looked like toys.'

In one of his aerial journeys Mr. Glaisher had the good fortune to see London under circumstances of unwonted brilliancy by night.

'The whole of Woolwich, Blackwall, Deptford, and Greenwich could be traced as a perfect model by the line of lights of their streets and squares. In nine minutes we were opposite Brunswick Pier. Blackwall; crossing the Thames, we then passed across the Isle of Dogs, Greenwich Reach, and so up the river Thames. As we advanced towards London the mass of illumination increased in intensity. At 6.42 (October 2, 1862) the South Eastern Railway Terminus at London Bridge was directly under us; looking southward at this time we saw the Borough stretching far away, and the many streets shooting from it, particularly Southwark Street with its graceful curve of lamps. In one minute more we were over Southwark Bridge, passed Blackfriars Bridge at 6.45, and Charing Cross at 6.47.

'On leaving Charing Cross I looked back over London,



BALLOON FLOATING ON WATER.

the model of which could be seen and traced—its squares by their lights; the river, which looked dark and dull, by the double row of lights on every bridge spanning it. Looking round, two of the illuminated dials of Westminster clock were like two dull moons. Again, looking eastward, the whole lines of the Commercial and Whitechapel Roads, with their continuations through Holborn and Oxford Street, were visible, and most brilliant and remarkable. We were at such a distance from the Commercial Road that it appeared like a line of brilliant fire, assuming a more imposing appearance when the line separated into two, and most imposing just under us in Oxford Street. Here the two thickly-studded rows of brilliant lights were seen on either side of the street, with a narrow dark space between, and this dark space was bounded as it were on both sides by a bright fringe like frosted silver. At first I could not account for this appearance; but presently, at one point more brilliant than the rest, persons were seen passing, their shadows being thrown on the pavement, and at once it was evident this rich effect was caused by the bright illumination of the shop-lights on the pavements.

'I feel it impossible to convey any adequate idea of the brilliant effect of London, viewed at an elevation of 1,300 feet, on a clear night when the air is free from mist. It seemed to me to realise a wish I have felt when looking through a telescope at portions of the Milky Way, where the field of view appeared covered with gold dust, to be possessed of the power to see those minute spots of light as brilliant stars, for certainly the intense brilliancy of London this night must have rivalled such a view.'

The delight of seeing the world under so many new and beautiful aspects is enhanced by the sense of extraordinary quiescence which immediately ensues upon the dismissal of the machine from the ground. No matter how agitated the balloon before its departure, no matter how violent the circumstances under which the ascent is effected, the moment the last hold upon the solid earth is cast off all is perfect repose and stillness the most profound. The creaking of the car, the rustling of the silk, the heavy lurching of the distended sphere swayed to and fro by the breeze, and shifting its load with sudden and energetic motion, despite the efforts of those who are struggling to retain it, all have ceased in an instant, and are succeeded by a degree of tranquillity so intense as for a moment to absorb all other considerations. However rapidly it may move, the balloon seems to stand absolutely still, so that instances are not unfrequent in which the aeronaut had risen to a considerable height before he was aware that he had left the earth. As the balloon travels with the wind, the resistance of the air felt in all other modes of motion is wanting, and the clouds, hurrying along in the same direction and with the same rapidity, seem as immovable as rocks.

Hence in many cases the aeronaut can only ascertain whether he is rising or falling by throwing bits of paper out of the car, which are left below or above, accordingly as the balloon is soaring upwards or descending. When the balloon burst in which Albert Smith ascended at Vauxhall, and he and his companion were precipitated with the rapidity of a stone falling down upon the earth, they could only by this means judge of the rapidity of their descent. While carried along by a dreadful hurricane Mr. Green perceived nothing of its violence, or of the speed with which he was careering through the air. He had all the time the same feeling of tranquillity as if he had been quietly seated in his arm-chair near the fire; and it was only on approaching the earth, and when the balloon was held fast by the grapnel, that he felt the fury of the gale.

Thus from the first moment that he casts off the shackles that erewhile bound him to the earth, a train of pleasurable emotions awaits the aeronaut. With the ease of an ascending vapour he rises into the atmosphere, carried aloft by the imprisoned gas, which like a sentient being responds to all external influences, and obeys every variation of pressure, temperature, or humidity. Even the most timorous lose their sense of fear as the balloon rises and the receding earth is replaced by the vapours of the air. Instead of shuddering, as might fairly be expected, at the enormity of the abyss which separates them from the earth, instead of drawing back as it were into themselves to escape the full consciousness of their precarious situation, they are astonished to find themselves intently poring over the new leaf of nature presented to their view.

Travellers, it is said, are apt to draw largely on the credulity of their hearers; and thus we cannot wonder that aeronauts, not satisfied with depicting reality, should sometimes have indulged in fables which might do credit to the inventive genius of Baron Munchausen. Mr. Monck Mason mentions a gentleman[1] who asserted that upon one occasion, in company with his son, he ascended to such an elevation that the wrinkles of his face had entirely disappeared through the preternatural distension of his skin, and to the astonishment of his companion, although long past his grand climacteric, he had actually begun to assume the aspect and appearance of his former youth!

Another aerial traveller, unwilling probably to be outdone in the race of aerostatic notoriety, positively declared that at the enormous elevation to which he had risen, his head, swollen by the diminished pressure of the air, had become so much *enlarged* that he could no longer wear his hat! On a third voyager altitude produced the opposite effect, as he was unable to keep his hat from tumbling over his eyes, so much had his head been *contracted* by the intense cold of the upper regions.

While the pleasures of the aeronaut are of a peculiar nature, he has also to contend with many troubles and dangers peculiar to this mode of travel. Often before ascending his patience is put to a severe trial by the slow or imperfect filling of his balloon with gas. This operation, as we have repeatedly seen in the last chapter, was particularly tedious during the first period of aeronautics, when hydrogen was the only gas employed for this purpose; but even since it has been supplanted by carburetted hydrogen, which, though heavier, is more easily procurable from a gasometer, hours often elapse before the balloon is sufficiently filled to carry its heavy weight into the air. If, while this operation is proceeding, a tolerably sharp wind arises, the balloon, impatient to take its flight, can only with the greatest difficulty be restrained. On August 15, 1859, a committee of the British Association met at Wolverhampton, to assist at the first departure of the 'Great Nassau Balloon,' which was intended to make aerial experiments and observations in and above the clouds. The weather was fine when the filling was begun, but the wind arose and many accidents happened which prevented the filling of the balloon taking place, so that the ascent was deferred till August 16. The committee was again at its post on this day, but, as it proved, only to see an aerial shipwreck. When many thousands of feet of gas had been introduced into the balloon, the wind arose and blew it with such violence that it was torn and all the gas escaped.

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[1] 'Aeronautica.'

The delays and difficulties which so often retard the balloon's departure are especially painful to the professional aeronaut, who has engaged to ascend at a stated time, and, unable to keep his promise, is at a loss to pacify the growing impatience of the public. More than once one of these bold men, to avoid unmerited reproaches, has ventured to rise in a half-filled balloon, and thereby placed his life in the greatest danger. In one instance, Mr. Henry Green (like his brother, an aeronaut of considerable notoriety), being unable to procure gas enough to raise the weight usually required, began by rejecting in succession every article which could be conveniently spared, and, failing to attain the necessary buoyancy, finally cut away the car itself, and, assuming a seat upon the bare hoop, rose to a very considerable altitude before he concluded his career.

On September 8, 1846, M. Arban, a French aeronaut, performed a similar foolhardy journey at Trieste. His balloon, from some defect in the preparation of the gas, had kept the public waiting for several hours, so that he at length resolved to leave the car behind. After removing under some pretext or other the attending police-officer, and his own wife who was to have accompanied him, he quickly cut away the car, and, binding together the ropes which attached it to the balloon, sat down upon them and rose, to the great astonishment of the spectators, whom he saluted with his right hand while his left grasped the cordage. The balloon rose majestically in a vertical direction, when the wind drove it westwards over the sea. For nearly an hour the spectators could follow it with their eyes, until at length it lost itself in the clouds. No one doubted that Arban, like his predecessor the unfortunate Zambeccari, must eventually be precipitated into the Adriatic; and the sympathy of the public was increased by the despair of his wife, who spent many anxious hours on the extreme end of the Molo San Carlo. A number of barks at once put out to sea in the direction which the balloon was supposed to have taken, but the night was spent without any knowledge of what had become of Arban. At length, on the following morning, a fishing-boat appeared with the bold aeronaut on board. The skipper had met with the half-filled balloon floating in the sea, and saved Arban, who had been three hours up to his shoulders in the water, from a certain death. Less fortunate than this foolhardy aeronaut, whose immersion had no other evil consequences for him than a fever, two American aerial travellers became the victims of an imprudent ascent on September 30, 1871. During an agricultural exhibition at Paola in the State of Indiana, Professor Wilber was making preparations for a balloon voyage in which he was to be accompanied by Mr. Knapp, the editor of a local newspaper. Before they could enter the car the balloon was prematurely loosened, so that when it rose they only held fast by the ropes. Knapp immediately let go his hold and fell from a height of thirty feet upon the ground, without sustaining any material injury. Wilber, however, continued holding fast to the rope and attempted to climb into the car; this, however, he was unable to accomplish, and the balloon carried him up into the air with the rapidity of an arrow. When about a mile high his strength failed, and he fell down upon the earth, where his body was, of course, broken into a shapeless mass.

After the balloon has safely left the earth new dangers await it in the upper regions. Sometimes the inflated globe bursts, in consequence of the expansion of the gas in the rarefied atmosphere.

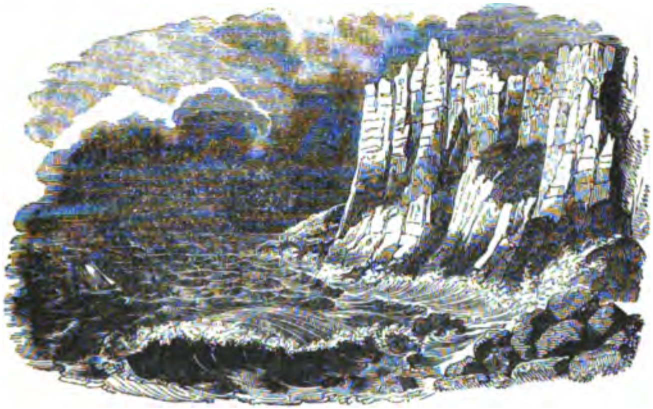
On July 9, 1847, Messrs. Coxwell and Gypson, with some other gentlemen, had ascended from Vauxhall Gardens to a height of 1,000 feet, when it was perceived that the balloon became very much stretched and distended. Coxwell immediately pulled the rope of the valve, which, however, from some cause or other, would not open. Soon afterwards a noise was heard like that which accompanies the discharge of steam from a locomotive, while, at the same time, the lower part of the balloon rapidly collapsed and contracted towards the upper part. Immediately the balloon began to fall with a dreadful velocity. Two of the company broke out into exclamations of terror and dismay, and every moveable article was at once thrown out of the car to diminish the weight, though without any sensible effect. Soon the houses of London seemed to rise up against them, and a moment after they fell upon the earth with a dreadful shock, which threw them out of the car and so entangled them in the netting and silk of the balloon that they could not move, and must inevitably have perished if they had fallen into the Thames. Incredible as it may seem, none of them was seriously hurt; torn clothes, ruined hats, and some bruises and contusions were the only evil consequences of a fall from a height of 6,000 feet.

A fortunate circumstance to which they probably owed their lives is, that in this and similar cases the collapsing balloon generally spreads out like a sail, so as to form a kind of parachute, which weakens the impetus of the fall. In this manner the American aeronaut, Mr. Wise, descended twice in a burst balloon without having sustained any serious injury.

The landing of a balloon can frequently only be accomplished with great difficulty and danger, and is, indeed, generally the most trying part of the whole journey, particularly when circumstances occur which require a precipitate descent. On April 18, 1867, Messrs. Glaisher and Coxwell ascended from the Crystal Palace to a height of 24,000 feet. When they were just four miles high they began to reflect that, as the weather was windy, they possibly might have been moving more quickly than they expected, and it was necessary to descend till they could see the earth below.

'On breaking through the clouds,' says Mr. Glaisher, 'still 10,000 feet from the earth, I was busy with my instruments, when I heard Mr. Coxwell exclaim, "What's that?" He had caught sight of Beechy Head. I looked over the car and the sea seemed to be under us. Mr. Coxwell again exclaimed, "There's not a moment to spare; we must save the land at all risks. Leave the instruments!" Mr. Coxwell almost hung to the valve-line, and told me to do the same and not to mind its cutting my hand. It was a bold decision opening the valve in this way, and it was boldly carried out.

'When a mile high the earth seemed to be coming up to us. There were two rents in the balloon cut by the valve-line, these we could not heed. Up, up, the earth appeared to come, the fields momentarily enlarging, and we struck the earth at Newhaven very near the sea—of course with a great crash, but the balloon, by the very free use of the valve-line, had been crippled, and never rose again or even dragged us from the spot on which we fell.' Nearly all the instruments were broken; but thanks to Mr. Coxwell's determination and presence of mind, which caused the balloon's descent in close proximity to the sea, the travellers had a narrow escape from a dangerous immersion.



BEECHY HEAD.

On August 15, 1863, Messrs. Duruof and Tissandier ascended at Calais, and found themselves surrounded by a thick fog at a height of 6,000 feet. A continuous and melodious sound reached their ears, but it was both menacing and terrible. Could it be the ocean? The question was soon answered, for by allowing some gas to escape they soon sank through the clouds, and perceived below not the earth and a green country, but an immense expanse of sea. The sun was about to sink into the waves, which it coloured with a thousand splendid tints. Their perilous situation, however, did not allow them to enjoy the magnificent spectacle, for, though a powerful breeze carried them towards a narrow promontory, it was very uncertain whether the balloon would reach the land, or whether it would rush past its extreme point and carry them on over the vast ocean, where a watery grave seemed to await them. Fortunately the wind decided in their favour; they pulled the valve-rope, threw out the grapnel, and let go the anchor at the right moment. The balloon striking on a sand-hill, rolled over on its side with the rapidity of lightning. They landed in safety a few hundred yards from the spot where Pilâtre de Rozier had come to an untimely end.

Even after the balloon has been brought to a standstill some careless management may still give the wind an opportunity to vent its spite and cause the aeronaut's destruction, when to all appearances he had but to step out of the car to terminate his voyage.

On the day of the ascent that was to prove fatal to Mr. Windham Sadler the weather was extremely rough, so much so, indeed, that a gentleman who had intended to be his companion refused to proceed with him, and his place was taken by a servant. At the conclusion of the voyage, and after a considerable quantity of gas had been allowed to escape, the rope by which the balloon had been retained was, by some neglect or other on the part of the bystanders, suddenly let go. The balloon, borne from the ground more indeed by the force of the wind than its own ascensive power, immediately sprang up, and, sweeping violently along, brought the car into contact with the chimney of a house. The luckless aeronaut fell over the side of the car, and, after hanging for a few seconds suspended by the feet, was finally precipitated on the ground near the town of Blackburn, on September 29, 1824.

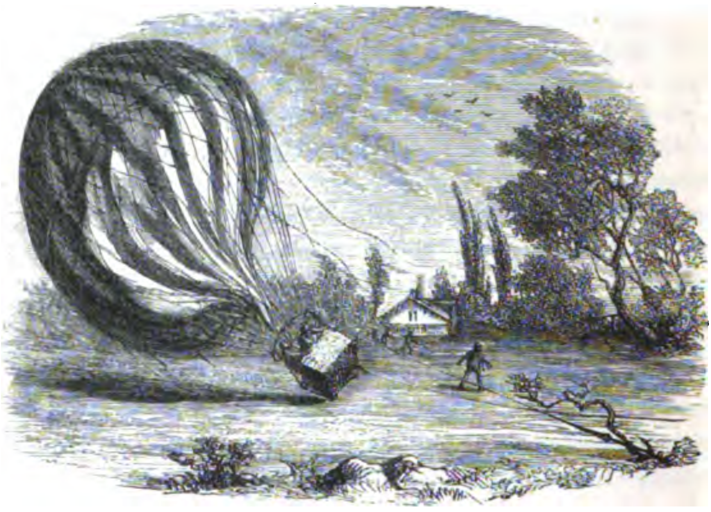
Even the villany of man has been known to beset the aeronaut's path with dangers. In an ascent from Cheltenham in the year 1823, in which Mr. Green was accompanied by

Mr. Griffiths, some scoundrel contrived partially to sever the ropes of the car in such a manner as not to be perceived before the balloon had risen from the ground. When they received for the first time the whole weight of the contents, they suddenly gave way, not, however, before the aeronauts had time to secure a painful and precarious attachment to the hoop. Lightened of its load, by the falling out of the ballast contained in the car, the balloon ascended with frightful rapidity, and before Mr. Green could gain possession of the valve-string, which the suddenness of the accident had placed beyond his reach, attained an altitude of upwards of 10,000 feet. This situation at this juncture may be compared to that of the shipwrecked mariner embracing the mast which bears him along on a tumultuous ocean. Clinging to the hoop with desperate energy, not daring to rest any portion of their weight upon the margin of the car that still remained suspended by a single cord beneath their feet, lest that also might give way and the lightened balloon soar to a still greater height, all they could do was to resign themselves to chance, and endeavour to maintain their hold until the exhaustion of the gas should have put a stop to their upward career. To complete the horrors of their situation, the network, drawn awry by the unequal distribution of the weight, began to give way about the upper part of the machine, mesh after mesh snapping with a succession of reports like those of a pistol, while through the aperture thus created the balloon began to ooze out, and, swelling as it escaped beyond the fissure, presented the strange spectacle of an enormous hour-glass floating in the upper regions of the sky. After having continued for a considerable time in this dreadful situation, every moment expecting to be precipitated to the earth by the final detachment of the balloon, they at length began slowly to descend. When they had arrived within about a hundred feet from the ground—and very fortunately not before—the event they had anticipated at length occurred: the balloon, rushing through the opening in the network with a tremendous explosion, suddenly made its escape, and they fell to the ground bruised and wounded, but saved as by a miracle from the death to which a fiendish perversity had exposed them.

Unfortunately, the author of this premeditated villany remained undiscovered, although a large reward was immediately offered for his detection.

From the moment the balloon rises it may truly be said to become a plaything of the winds. Unfelt while it sails along through the air, they may become highly dangerous at the termination of its voyage, either by trailing it furiously along the ground, or bringing it into collision with trees or houses.

The following account of Mr. Nadar's aerial journey from Paris to Hanover in the 'Géant' gives us a good idea of the sensation of the aeronaut when, on attempting to alight, his balloon becomes the prey of the winds and makes prodigious bounds over the surface of the earth.



BALLOON FURIOUSLY TRAILING ALONG THE GROUND.

The monstrous aerostat, which well deserved its name, as it required 200,000 cubic feet of gas for its filling, and carried a car of two stories, provided with all the conveniences that might be required for a journey of several days, ascended on October 18, 1865, from the Champ de Mars with a company of nine persons. Half Paris had assembled to witness its departure, which took place at six o'clock in the afternoon. The 'Géant' rose majestically into the air—the miserable termination of its flight only became known three days later. After a rather comfortless night's journey, the balloon was sailing over a wide plain covered with fog, which the geographers of the company supposed to be part of Holland, and, as Mr. Nadar feared the vicinity of the sea, he gave the signal to descend. The valve, however, in consequence of some defect, could not be widely enough opened, so that the gas did not escape with sufficient rapidity—and, to make matters worse, a violent wind drove the distended 'Giant' before it. From the environs of Nienburg, where the first attempt to descend was made, the subsequent voyage of the balloon consisted of a continual series of enormous bounds over fields and meadows, over trees and hedges—a steeplechase on the grandest scale. The grapnel had already been lost near Nienburg.

'The shocks,' writes one of the sufferers, 'repeat themselves after constantly shorter pauses, so that at last we can no longer count them. Like an elastic ball which an indefatigable hand keeps constantly striking to the ground, and which as constantly rebounds, our car springs up fifty or a hundred feet high at every shock. By a deplorable oversight it had been unequally freighted from the very beginning of the voyage. All the passengers, without advice or experience, were close together on one side of the machine, so that the car always struck on this heavily-laden part and made us feel severely every concussion. What a vertiginous rapidity! what a succession of shocks, thick as hail! what a tension of the muscles, of the will!—for one moment of faintness and inattention, and one is flung out into the air! And every shock tears our muscles, sprains our wrists, dislocates our arms, throws us violently one against the other.

'The rapidity of our insane career allows our eyes to catch but a few of its incidents. A solitary tree advances towards us with lightning velocity—we break it like a piece of straw. Two terror-struck horses, their nostrils to the ground and with flying manes, run as fast as they can to escape us—but we rush past, and leave them far behind. But now a danger, a serious danger, approaches; for right before us a locomotive with its tender and two waggons is rolling along. The wheels need but revolve a few times more and the collision is inevitable. No doubt that in our hurricane career we shall overturn the slow machine, but we also shall be bruised, crushed, and torn to pieces. But a few mètres separate us from our enemy—a cry of terror—the locomotive answers with a shrill whistle—it moves backwards—just in time to avoid the shock. Take care of the wires, for there they are staring us right in the face, the four wires of the electric telegraph—as many guillotines—but fortunately we fly over them.'

At length, by throwing out ballast, the 'Géant' was again made to rise and a stop put to its terrible bounds. The valve was opened, and the balloon collapsed; but it still continued for a time to be the plaything of the furious wind, until at last it remained hanging in the trees of a forest. As soon as the car approached the earth those of its passengers who were still able to move jumped out. Most of them were severely wounded; none escaped unhurt.

Another interesting case of dragging occurred on February 6, 1869, when MM. Fonvielle and Tissandier ascended in stormy weather in a small balloon, the 'Swallow.' After a short time, the machine appeared to be emptying itself of gas, so that they were obliged to throw out ballast every moment. The balloon, however, continued to sink with great rapidity, so that to avoid some dangerous quarries and precipices they threw away their last bag of ballast. A gust of wind now carried them in one bound over a wide plain, at the extremity of which they saw a considerable extent of forest. This was the spot to descend upon. The car came down with a terrible shock, but rose again immediately, and, dragged along by the force of a furious gale, alternately bounded into the air and violently struck against the earth.

'So rapid was our flight,' says M. Tissandier, 'that we could not distinguish the various objects which we passed by, and in less than a second we found ourselves thrown on the tops of the trees at the extremity of the plain. We hoped that the branches would split open the balloon and put an end to our furious course. The anchor was broken, and nothing but its ring remained at the end of the rope—our only hope was thus dashed to pieces.' Holding on to the valve-rope with all his strength, and, squatting down at the bottom of the car, Tissandier pulled away lustily, whilst the 'Swallow' jumped about from one tree to another. 'The branches of the trees bent beneath the car, the wind whistled in our ears; the balloon appeared to have lost some gas, but a sudden gust carried it from the wood again, and down it came with a hard bump upon the open plain beyond. The wind now hollowed the balloon into a kind of cup or basin, and carried us vigorously across the ploughed land; until finally some men ran up and caught hold of the guide-rope.' The bruised and wounded aeronauts had landed at Neuilly St. Front, which is about forty-eight miles from Paris as the crow flies; and on looking at their watches were astonished to find that it was only thirty-five minutes since they left the gasworks in Paris. They had therefore travelled at the hurricane rate of ninety miles per hour, a speed which probably no balloon has ever equalled.

The sight of a balloon floating towards them makes a deep impression upon all animals, especially upon birds, who, probably mistaking it for some winged monster ready to pounce upon them, show the greatest alarm at its approach. The cows in the fields seem to acknowledge the presence of an enemy, and exhibit as much confusion as it is possible to express by tails erect and accelerated paces. As it passes over a marshy country, the numerous flocks of ducks and geese, which delight in a swampy situation, may be seen running in every direction to seek a shelter from the foe, that appears like a stupendous falcon hovering above their devoted heads. 'I have frequently,' says Mr. Monck Mason,[1] 'observed with much interest the proceedings of a colony of rooks acting under the influence of these alarms, at a time when the progress of the balloon happened to be more than ordinarily accelerated by a stiff breeze. Aroused from their airy habitations, and unable, no doubt, at first to fathom the powers and intentions of this novel apparition, they seem to content themselves with advancing leisurely by short stages, occasionally stopping whenever they have reached a certain distance, and again renewing their retreat as the balloon begins to diminish the interval which they seem desirous to maintain between them. Finding, however, the inutility of these desultory efforts, and perceiving the mighty object of their terrors gradually gaining ground upon them, they soon abandon their former line of conduct, and, taking the direction of the balloon, seek in a continuous flight to evade the antagonist with which they have apparently no other mode of contending. In this manner they persist, vainly increasing in their exertions, until at length the balloon, having attained a position directly above them, they suddenly stop short, seem to hesitate for a moment in dismay, and, finally, after a brief but stormy debate, adjourn in confusion, scattering themselves in every direction over the surface of the earth beneath.'

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[1] 'Aeronautica.' London, 1838, p. 223.

CHAPTER XXXV.

THE 'GREAT NASSAU' BALLOON.

Ascent of Messrs. Green, Hollond, and Monck Mason from Vauxhall Gardens on November 7, 1836—Crossing the Channel—A Thick Barrier of Clouds—Over Belgium and Northern France by Night—Across the Rhine—Boundless Prospect—Landing near Weilburg—Triumphal Reception—Latin Verses in Honour of the Aeronauts—Charles Green the First Aeronaut of the Age—His Long and Successful Career.

THE successful voyage of the 'Great Nassau' balloon, from the banks of the Thames to those of the distant Lahn, will always be remembered as one of the greatest and most interesting feats in the history of aerostation.

With extreme difficulty, in constant danger of being swallowed by the waves, Blanchard and Jeffries had, in the infancy of the art, ventured to fly across the Channel, and ever since all aeronauts had dreaded the sea as a formidable enemy.

But the 'Great Nassau' balloon, as it was subsequently called, constructed of colossal dimensions and provided with every imaginable requisite, and provisions to last a fortnight, or longer if need be, afforded ample security against the disasters of an ordinary voyage; and when, on November 7, 1836, Mr. Robert Hollond, the projector of the enterprise, Mr. Monck Mason, its historian, and Mr. Charles Green, the first aeronaut of the age, ascended in its car from Vauxhall Gardens, they never gave the danger of an immersion in the sea a moment's thought, fully assured that their gigantic balloon would carry them, as they intended, far into the interior of the Continent.

At half-past one o'clock the balloon was dismissed from the ground amid a vast concourse of people, and, rising gently under the influence of a moderate breeze, bore speedily away towards the south-east, traversing in its course the cultivated plains of Kent, and passing in succession nearly over the towns of Eltham, Bromley, Footscray, and others, whose variegated outlines beautifully diversified the landscape. Rochester, the Medway, and the lofty towers of Canterbury, successively made their appearance, and soon after the sea, brightening under the last rays of the setting sun, glittered at the extreme verge of the horizon. During the latter period of this part of the voyage, the balloon, perhaps owing to the condensation occasioned by the approaching shades of evening, had been gradually diminishing its altitude, and for some time past had continued so near the earth as to permit the aeronauts, without much exertion, to converse with such persons as happened to be in their immediate vicinity. So close, indeed, were they at one time, as to be able distinctly to observe a covey of partridges, which their approach had dislodged from their resting-place. A whole colony of rooks, alarmed, no doubt, by their formidable appearance, rose likewise in dismay, and, vainly trying the protection of the neighbouring woods, finally dispersed, scattering themselves in every direction over the surface of the earth beneath.

Shortly after the balloon had lost sight of the city of Canterbury, a considerable deviation appeared to have taken place in the direction of her route. Instead of pursuing her former line of south by east, it became apparent that her gradual descent to a lower level had brought her under the influence of an aerial current which tended considerably to the northward, and was carrying her away in the direction of the North Foreland.

Some ballast was thrown out, and the balloon, slowly rising and sweeping majestically round the horizon, in obedience to the double impulse of her increasing elevation and the gradual change of current, placed her in a few minutes almost vertically over the Castle of Dover, in the exact line for crossing the straits between that town and Calais, where it is confined within its narrowest limits.

'Up to the present moment,' says Mr. Monck Mason, 'nothing had appeared calculated to confer particular distinction upon our enterprise, or to awaken the impression that what we had undertaken differed in any respect from the usual class of such excursions. The case, however, was now shortly to be changed; a new and untried element was about to enter upon the scene, producing new relations and requiring the exercise of new resources. . . . It was forty-eight minutes past four when the first line of waves, breaking on the beach, appeared beneath us, and we might be said to have fairly quitted the shores of our native soil, and entered upon the hitherto dreaded regions of the sea.

'It would be impossible not to have been struck with the grandeur of the prospect at this particular moment of our voyage. Behind us, the whole line of English coast, its white cliffs melting into obscurity, appeared sparkling with the scattered lights, which every moment augmented, and among which the lighthouse of Dover formed a conspicuous feature, and for a long time served as a beacon whereby to calculate the direction of our course. On either side below us the interminable ocean spread its complicated tissue of waves without interruption or curtailment, except what arose from the impending darkness and the limited extent of our own perceptions.

'On the opposite side a dense barrier of clouds, rising from the ocean like a solid wall, fantastically surmounted throughout its whole length with a gigantic representation of parapets and turrets, batteries and bastions, appeared as if designed to bar our further progress, and completely obstructed all view of the shores towards which we were now rapidly drawing nigh. Upon the glittering plain which thus lay stretched before us, a few straggling vessels, some of which had already began to mount their lights, alone appeared, issuing from beneath the dark mantle of clouds, that rested, as it were, upon the very bosom of the deep. In a few minutes after, we had entered within its dusky limits, and for a while became involved in the double obscurity of the surrounding vapour, and of the gradual approach of night. Not a sound now reached our ears; the beating of the waves upon the British shores had already died away in silence, and from the ordinary effects of terrestrial agitation our present position had effectually excluded us.'

In the short space of about one hour the sea was crossed; the cloudy barrier withdrew its veil, and the well-known lights of Calais and of the neighbouring shores glittered beneath the aeronauts. The night completely closed in, and, as they advanced, the countries they were traversing exhibited a scene worthy of fairyland. 'The whole plane of the earth's surface, for many a league and league around, seemed absolutely teeming with the scattered fires of a watchful population, and exhibited a starry spectacle below that almost rivalled in brilliancy the remoter lustre of the concave firmament above. Incessantly during the earlier portion of the night, ere the vigilant inhabitants had finally retired to rest, large sources of light, signifying the presence of some more extensive community, would appear just looming above the distant horizon in the direction in which we were advancing, bearing at first no faint resemblance to the effect produced by some vast and distant conflagration. By degrees, as we drew nigh, the confused mass of illumination would appear to increase in intensity; it would gradually resolve itself into its parts, and, shooting out into streets or spreading into squares, present us with the most perfect model of a town, diminished only in size according to the elevation from which we happened at the time to observe it.'

Thus, wafted by a gentle breeze over Northern France and Belgium, the balloon reached about midnight the populous city of Liège, which, with the innumerable fires of the extensive ironworks abounding in its neighbourhood, formed by far the most interesting feature of their nocturnal journey.

The perfect correctness with which every line of street was marked by its particular line of fires, the forms and positions of the more important features of the city, the theatres and squares, the markets and public buildings, indicated by the presence of the larger and more irregular accumulation of lights, added to the faint murmur of a busy population still actively engaged in the pursuits of pleasure or the avocations of gain—all together combined to form one of the most striking pictures it is possible to conceive.

After passing the town, and the fiery district in which it is embosomed, the extinction of every light and the hushing of every sound into silence, proclaimed that the world and its inhabitants had finally committed themselves to repose. The sky, at all times darker when viewed from an elevation than it appears to those inhabiting the lower regions of the earth, seemed almost black with the intensity of night, while, by contrast, the stars shone with redoubled lustre from its jetty dome. Occasionally faint flashes of lightning, proceeding chiefly from the northern hemisphere, would for an instant illuminate the horizon, and, after disclosing a transient prospect of the adjacent country, render the darkness more obscure than ever. It was as if they were cleaving their way through an interminable mass of black marble in which they were imbedded, and which, solid a few inches before them, seemed to soften as they approached, in order to admit them still farther within the precincts of its cold and dusky enclosure.

At length this Cimmerian darkness gave way to the approach of dawn, and an irregular surface of cultivated country began feebly to display itself, in the midst of which a majestic river appeared dividing the prospect, and losing itself in opposite directions behind the gently swelling eminences by which it was bordered on both sides. Across this river—the 'exulting and abounding' Rhine—they now directed their course, and about a quarter past six, the balloon having risen to an elevation of about 12,000 feet, suddenly brought them in full view of the sun, and for the first time gladdened them with the assurance of a speedy return of day.

'If we only reflect,' continues Mr. Mason, 'that our position at this altitude was such as to have enabled us to behold objects at a distance of above one hundred and fifty miles on every side of us, had those objects been sufficiently great or sufficiently striking to fix the attention, some faint idea may be had of the immensity of prospect which at that moment became subjected to our view. . . . Powerful indeed must be the pen which could hope to do justice to the scene which it presented to our view. The enormous extent of the prospect—the boundless variety it embraced, the unequalled grandeur of the objects it displayed, the singular novelty of the manner under which they were beheld, and the striking contrast they afforded to that situation and those scenes to which we had so long and so lately been confined—are effects and circumstances which no description is capable of representing in the light in which they ought to be placed in order to be duly appreciated.

'This splendid spectacle, however, we were not long destined to enjoy, a rapid descent, which shortly after ensued, for a while concealing it from our view, and once more consigning us to the shades of night, which still continued to reign unbroken throughout the lower regions of the air.

'Again we rose within the reach of this delightful prospect, and again did we lose sight of it, amid the vapours and obscurity that accompanied our descent; nor was it till we had three times made the sun rise, and twice beheld it set, that we could fairly consider it established above the horizon, and daylight complete upon the plane of the earth beneath us.'

Ignorant of the distance they had come, and fearing, from the large tracts of snow which covered the earth, that they might be approaching the boundless plains of Poland or the inhospitable steppes of Russia, they now resolved to descend, before the winds wafted them too far beyond the pale of civilisation. Quitting their exalted station in the clouds, they consequently sought a more humble level, along which they continued to range for some time and to a considerable distance, the early hour of the day deterring them from completing the descent, in the fear of not obtaining that ready assistance from the inhabitants which it is always the main object of the aeronaut if possible to secure.

As the mists of the night began to clear away from the soil, they were delighted to perceive a country intersected with roads, dotted with villages, and enlivened with all the signs of an abundant and industrious population. The snowy covering which so lately chilled them with its forbidding aspect, had now disappeared, except a few patches which still lingered in the recesses of the numerous hills by which the surrounding neighbourhood was particularly distinguished. On the summit of one of these a large castle appeared just breaking through the vapours that yet partially concealed the morning landscape. One or two towns, likewise of superior pretensions, were distinctly to be seen, giving promise of accommodation, and of every assistance their situation might require. Accordingly, having pitched upon the spot most proper for the purpose, the valve was opened, and they commenced their descent. The place they selected was a small grassy vale embosomed in hills, whose sides and summits were completely covered with trees. To effect a landing on this narrow spot was no easy matter, but the skilful manœuvring of their experienced captain succeeded in keeping the balloon clear of the woods and bringing it safely to the ground.

As soon as the descent was completed, and the power of the balloon sufficiently crippled to permit one of the party to quit the car, the inhabitants, who had hitherto stood aloof, regarding their movements with considerable suspicion, began to flock in from all quarters. A few words in German served to dissipate their fears and secure their services. The first question, 'Where are we?' was speedily answered, 'In the Duchy of Nassau, about two leagues from the town of Weilburg.' The second was theirs, 'Where do you come from?' 'From London, which we left yesterday evening.' Their astonishment at this declaration may be easily conceived, as well as the satisfaction with which they regaled on the biscuits, wine, and brandy which the aeronauts liberally bestowed upon them. The brandy in particular, so much superior to any spirituous liquor they had ever before tasted, attracted their special admiration, and, as they each in succession drank off their allowance, they seemed, by the exclamation of 'Himmlischer schnapps' (celestial dram), as well as by the upward direction of their eyes, to denote the quarter from whence so delicious a beverage could alone have proceeded.

A waggon, having been procured, was loaded with the empty balloon, and, mounting on the primitive vehicle themselves, the aeronauts, now reduced to a more humble mode of locomotion, set out for Weilburg, attended by an amazing concourse of persons of every rank, age, and sex, and preceded by the fame of their adventure. On their approach they found themselves greeted with acclamations, and a most hospitable welcome. All the resources of the town were immediately placed at their disposal; the use of the ducal riding-school was tendered for the occupation of the balloon, and sentries—more, indeed, as a guard of honour than of protection—stationed at the doors and avenues leading to the place of its reception. During the whole period of their residence at Weilburg, already by a curious coincidence noted in the annals of aerostation as the place where the celebrated Blanchard effected his landing after an ascent which he made at Francfort in the year 1785, they were the objects of the most flattering attentions, and on the eve of their departure, which took place on November 20, a grand festival, attended by all the first personages of the small town, was held in their honour. On this occasion the following lines from the pen of Dr. Friedemann, director of the Gymnasium of Weilburg, were addressed to Mr. Green:—

Carolo Greenio,

Britanno, Artifici peritissimo et clarissimo.

Olim Blanchardus, nostras delapsus ad oras
Insolitâ clarum nomen ab arte tulit,
Sed breve per spatium, Mœno Taunoque relicto
Finis erat celeris Vilinaburga viæ.
Nunc post lustra decem, majus quid Greenius ausus,
A Tamesi ad Lanam deproperavit iter,
Per mare, per fluvios, montes transgressus et urbes,
Nec noctis tenebras horruit impavidus.
Cedite Romani, Graii quoque, cedite Galli;
Dædaleam laurum Greenius unus habet.

To Charles Green.

In former days the Gallic Blanchard came
To Weilburg's humble shores in search of fame,
But short his flight, and brief his bold career,
From Francfort and the Maine transported here.
But who is he that now with bolder span
Flies from the Thames to settle on the Lahn,[1]
O'erleaping empires in his daring flight,
Regardless of the sable frowns of night?
Yield Romans; yield Greeks; Frenchmen, quit the throne—
The crown of Dædalus is Green's alone.

Translated by Mr. Monck Mason.

At the conclusion of this short oration, a crown of laurels was placed upon the head of Mr. Green, and his health, and that of his companions, drunk amid general and repeated acclamations.

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[1] The river on which is seated the town of Weilburg.

Thus triumphantly ended the most remarkable of the 1,400[1] ascents accomplished by Charles Green, during his long aeronautic career, which began in the year 1821 at the coronation of George IV. and continued for thirty-six years. That not all his excursions proved equally fortunate may as easily be conceived as that a soldier who takes part in many campaigns is not likely to escape without wounds or misadventures. Three times he crossed the sea and twice he fell into it;[2] but the most deplorable of all his aerial voyages was that which he undertook with the unfortunate Cocking, who fell a victim to a newly-invented parachute, in which the surface of least resistance was made to descend foremost. A parachute of this novel description was of course calculated to accelerate the descent of the person who trusted his weight to it, instead of breaking his fall; and, as might have been foreseen, its first trial proved fatal to the inventor.

On September 27, 1836, Green and Cocking ascended from Vauxhall Gardens with the ill-fated parachute fastened under the car, and Cocking seated in a basket beneath it. When at an elevation of about 5,000 feet the separation was effected, and the parachute commenced descending with a frightful velocity. In a few seconds it was observed to give way before the pressure to which it was subjected in its fall, and in less than two minutes the unfortunate adventurer was lying lifeless on the ground. When Green let Cocking descend, he nearly met with a fate as disastrous as that of his imprudent friend; for the detachment of so considerable a weight caused the balloon to fly upwards with the swiftness of a rocket. Though he pulled the valve-rope lustily, he rose at once into the icy regions where Zambeccari lost his fingers from the effects of the cold.

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[1] Or 6,000, according to another account.

[2] A new safety apparatus, invented by the celebrated aeronaut Sivel, considerably diminishes the danger of an immersion in the sea, and would no doubt have been of great service to M. and Mdme. Duruof, as they drifted along through the tumultuous waters of the German Ocean (September, 1874). Mr. Sivel drops into the sea a sort of canvas cylinder of a conical form, and held by a guide rope to the car. It fills with water, and is kept down by the weight of the liquid. He then throws out a little ballast and the balloon rises, but is retained like a captive one at a short distance above the sea. He can thus wait until a vessel comes to deliver him, or until he drifts to shore. Should he wish to rise again he pulls a cord attached to the point of the cone end, and which turns it upside down. The water escapes and the balloon is freed. This invention has been tried by him over twenty times at sea with perfect success.

Green, who died in 1870 at the patriarchal age of eighty-six, was seventy-three years old when he made his last ascent.

'It is to be regretted,' observes Mr. Glaisher, 'that his education was not sufficiently good to make him a competent observer in the higher regions of the atmosphere. However, he improved the general management of balloons in many particulars, invented the guide-rope which has proved itself of considerable use, particularly in crossing the seas, and was the first who introduced carburetted gas in the place of hydrogen—a substitution which, by rendering travels in the air less costly and of a more easy accomplishment, has done much to popularise the use of balloons.' He has thus acquired a lasting fame in the annals of aerostation, and well deserved the crown of laurels offered by Weilburg to the successful pilot of the 'Great Nassau' balloon.

CHAPTER XXXVI.

SCIENTIFIC AERIAL VOYAGES.

Robertson and Lhöest—Gay-Lussac and Biot—Carlo Brioschi—Rush—Messrs. Barral and Bixio—Sufferings in the Cause of Science—Mr. Welsh—Mr. Glaisher.

THOUGH Montgolfier's invention presented science with a new and invaluable instrument for studying the meteorological phenomena at elevations hitherto inaccessible to man, yet so tardy was its enlistment in the service of natural philosophy that many years elapsed before Robertson and Lhöest (July 18, 1803) made the first physical experiments in the upper regions of the air. Even now, while thousands of ascents have been performed in Europe and America for the sake of public amusement, very few have been undertaken with the view of increasing our knowledge; for the civilised nations of the world, profuse in their expenditure on instruments of destruction, or in the pursuit of barren entertainment, grow extremely economical whenever the mere advancement of science is in question. On referring to the report of their voyage which the above-mentioned aeronauts addressed to the Academy of Sciences of St. Petersburg, we find that they left Hamburg at nine o'clock in the morning, and after remaining five hours and a half in the air came down near Hanover, at about seventy-five miles from their starting-point. The balloon rose to 23,526 feet (?), the thermometer fell to 19·6° while it was 68° on the ground. In spite of the intensity of the cold and the feeling of faintness caused by the rarefaction of the air, Robertson made several experiments at the considerable elevation which he attained. Among others he exploded ten grains of chlorate of potash, which produced merely a sharp crack, but occasioned a painful sensation in the ear. The striking on several metallic bodies likewise produced a more feeble sound than on the surface of the earth. Unslaked lime was used for the purpose of heating a pot of water, in order to ascertain the degree of temperature at which it would boil at this height in the air; but by an unaccountable mistake, reminding us of the absent philosopher who immersed his watch in the hot water while he held the egg in his hand, Robertson plunged his thermometer into the lime instead of dipping it into the seething water, and so broke it. However, he felt it quite possible at this considerable altitude to hold his hand in the *boiling* water without experiencing the slightest inconvenience.

The Academy of Sciences of St. Petersburg resolved to have the experiments of the Hamburg expedition repeated, and to engage for that purpose the services of Professor Robertson, who accordingly ascended on June 30, 1804, accompanied by the academician Sacharow. On this occasion a great number of optical, electrical, and magnetic observations were to have been made; but as the instruments could not readily be used, and the practical embarrassments of balloon management were severely felt, the results were meagre and entitled to very little confidence, both from the inaccurate manner in which the experiments were made, and the exaggerated reports of the observers. Some credit, however, is due to the Russian Academy for having been the first learned society which patronised the scientific use of the balloon.

As Robertson and Sacharow had concluded from their observations that the intensity of the effects of terrestrial magnetism diminish at a greater elevation from the earth, and that the electrical phenomena likewise show remarkable deviations, the celebrated Laplace proposed to the French Academy of Sciences to fit out a balloon expedition for a more accurate and trustworthy investigation of these physical problems. In compliance with his wish it was soon decided that the two eminent *savants*, Gay-Lussac and Biot, whose zeal equalled their abilities, should make the first experimental ascent, which accordingly took place from the Conservatoire des Arts et Métiers on August 24, 1804. At an elevation of about 6,500 feet above the level of the sea they commenced their observations, from which, however, at that altitude, they obtained no results of sufficient importance to merit attention; unless, indeed, it can be considered as such that no difference was discernible in the action of the natural powers of magnetism, electricity, and galvanism, as far as they were tested, from what they would have displayed upon the surface of the earth. At an elevation of about 11,000 feet they liberated one of the birds with which they had been provided; for a moment it rested upon the edge of the car, and then launching into the deep abyss directed its course in gradually widening circles towards the earth, thereby refuting an erroneous opinion generally prevalent that the rarity of the atmosphere in such elevated situations was incompatible with the exercise of their natural functions.[1]

At the height of 13,124 feet they endeavoured, by means of a horizontal needle, to determine the magnetic intensity—this was, in fact, the chief object of their ascent—but the rotatory motion of the balloon presented an unexpected obstacle to these observations.

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[1] Robertson and Sacharow, forgetting, probably, the condor and others of the raptorial kind, had alleged the inability of birds to support themselves at a considerable height. They affirmed that one of the two birds they had taken with them was found dead when they were about to let it fly, and the other in a state of stupefaction. On throwing it out of the car—for it would not take flight spontaneously—it fell perpendicularly, like a lifeless thing, and with an extreme velocity. 'Nothing,' says Monck Mason, 'but a vainglorious desire of temporary praise, backed by an utter disregard to truth, could ever have induced them to admit an error which the united testimony of all who can be relied upon decidedly refutes.'

C. Green, in the course of his practice, frequently took up with him pigeons and other birds of various kinds, for the purpose of liberating them at a great altitude, and never found any reason to suspect that they suffered in the least as to the motive energies from the reduction in the density of the medium. On one occasion he let loose a pigeon at an elevation of about 6,000 feet, the earth being then totally excluded from view by a dense, impenetrable layer of intervening clouds. The bird, after quitting the car, ignorant where to proceed (never perhaps having been placed in a similar situation), continued to accompany the balloon for several hours, maintaining the same distance, and traversing the empty hemisphere with idle circles, until the shades of evening and his own descent finally excluded it from his view. Upon another occasion Mr. Green took up with him a tame goose (a bird not generally versed in the art of flying), and, at a considerable elevation, committed him to the exercise of his own resources. At first the bird, expressing a little proper astonishment at his novel situation, seemed disinclined to part company; being, however, at last persuaded to shift for himself, he began flying downwards, and so continued for about half a minute, till at length, perceiving the inutility of labouring to do that which could be effected without it, he desisted from his exertions, and, expanding his wings, allowed himself to descend in gradually increasing circles to the ground.

The results of their voyage not having realised the expectations of the scientific world in Paris, owing chiefly to the limitation which the weight they carried imposed upon their ascent, it was resolved to make another attempt, in which Gay-Lussac should go up alone. Accordingly, on September 16 in the same year, that celebrated chemist again ascended from the same place. Having supplied his balloon with long hanging ropes, destined to counteract the spinning motion of the machine, he was enabled to make some experiments with an oscillating magnetic needle, from which he concluded that the magnetic power does not undergo any notable change even at the greatest heights to which we can have access.

At an elevation of 21,500 feet, two large glass balloons, which had been previously exhausted of air, were opened for the purpose of collecting a portion of the atmosphere at this enormous height. Its subsequent analysis proved no difference whatever in its composition and that of the air at the level of the sea.

Having attained an altitude of 22,977 feet, and almost all his ballast having been spent, Gay-Lussac considered it prudent to arrest his farther progress. The appearance of the sky at this, the extreme point of his ascent, was particularly interesting; the colour, especially about the zenith, being comparable only to a deep shade of Prussian blue, while, notwithstanding his excessive elevation, he could still perceive clouds floating at an apparently immeasurable distance above his head. The temperature had fallen as low as 17·1° of Fahrenheit.

Although well clothed, he now began to suffer from the effects of the cold, especially in his hands, which he was obliged to keep exposed and constantly employed in handling the various instruments necessary in making observations. His respiration likewise he describes as being sensibly affected, and, as well as his pulse, considerably accelerated; not so much, however, as to occasion any great inconvenience, or to precipitate his descent. Owing to the increase in the rate at which the former function was performed, and the want of moisture of the atmosphere upon which it had to, act, it is not surprising that his throat should have become so dry that it was with difficulty he was able to swallow a few mouthfuls of bread. After having terminated his researches with all the quiet of a philosopher seated in his study, he came to the ground about six leagues from Rouen, having been altogether five hours and three quarters in the air.

Two years after this memorable ascent, the Astronomer Royal of Naples, Carlo Brioschi, wished to ascend higher than Gay-Lussac, but this he was unable to do in consequence of the bursting of his balloon.

A long period now elapsed before any new scientific aerial journey was again attempted. In 1838 and 1850 Mr. Rusk ascended several times with Mr. Green, and made some observations mainly on humidity. His researches were received with some interest by the public, but the ascents were chiefly known from an incident which occurred at the end of one of them. The balloon fell into the sea near Sheerness, and the car was dragged through the water with great rapidity, the balloon acting as a kite. Mr. Green therefore threw out the grapnel, which caught in a sunken wreck, and detained the balloon till a boat came up and secured the voyagers. A volley of musketry was fired into the balloon to admit of the escape of the gas, and it was ultimately secured.

In the year 1850, MM. Barral and Bixio conceived the project of ascending to a height of 30,000 or 40,000 feet, for the purpose of investigating certain atmospheric phenomena still imperfectly understood. They wished to determine the laws which govern the decrease of temperature and humidity with height; they also desired to examine the composition of the air at various elevations, and its contents with regard to the quantity of carbonic acid present; to compare the heating effects of the solar rays in the highest regions of the atmosphere with those observed at the surface of the earth; and to decide several other questions of an interesting character. Their ascent took place from the garden of the Paris Observatory on June 29, 1850, at twenty-seven minutes past ten in the morning, in a balloon filled with pure hydrogen gas. The weather was stormy; a torrent of rain fell, and, placing themselves in the car without testing the ascensional powers of the machine, MM. Barral and Bixio, and the aeronaut who piloted the expedition, darted into the air with the velocity of an arrow 'shot by bowman strong,' and soon disappeared among the clouds.

This rapid ascent was but the prelude of still farther misadventures, for the balloon becoming rapidly inflated, and pressing upon the network, which was far too small, bulged out at top and bottom, and, pressing down upon the aeronauts, soon covered them like an immense hood as they were seated in the car, which unfortunately was suspended by cords much too short. In this critical situation, one of the party, in his efforts to secure the valve-rope, made a rent in the lower part of the balloon, from which the gas, escaping at the height of their heads, nearly suffocated them.

A glance at the barometer showed that they were descending rapidly, and, seeking the reason of this unexpected occurrence, they found that the balloon was split open about the middle, and that the rent was upwards of two yards in extent. It was then evident that all they could hope for was to escape with their lives from this ill-managed and unlucky ascent. They threw overboard all their ballast, their wearing apparel, and their fur coats, every movable article, in fact, only excepting their instruments—the precious arms of the peaceful soldiers of science. At last they landed, at a quarter-past eleven, in a vineyard at Dampmart, near Lagny. The labourers and peasants who ran to their assistance found them clinging to the vines, to stop the horizontal drifting of the car over the ground. Though their voyage had been so short, it appears, according to the calculations, that they must have risen to a height of 19,000 feet.

Nothing daunted by the ill-success of their first expedition, and eager to obtain a better result from a second trial, Barral and Bixio determined to ascend again without delay. In the following month, July 27, the filling of the balloon was commenced early in the morning. It proved to be a long operation, occupying till nearly two o'clock; then heavy rain fell, the sky became overcast, and it was past four when they left the earth. They soon entered a cloud at 7,000 or 8,000 feet, which proved to be fully 15,000 feet in thickness. They never, however, reached its highest point, for when at 4 h. 50 m. the height of 23,000 feet was attained, they began to descend, owing to a rent which was then found in the balloon. After vainly attempting to check this involuntary descent, they reached the earth at 5 h. 3 s.

A very interesting *mirage*, or rather 'mock sun,' was noticed on this occasion. Before attaining the highest point, the layers of cloud which surrounded the balloon on all sides diminished very much in density, and the disc of the sun was seen through them faint and dim; at the same time there appeared below the horizontal plane, level with the car of the balloon, and at an angular distance from this plane equal to that which measured the apparent height of the sun, a second sun, like the reflection of the first from a sheet of water. This phenomenon was attributed to the reflection of the sun's rays from the horizontal planes of crystals of ice floating in the atmosphere.

The most unexpected result, however, observed in this ascent was the extraordinary decrease of temperature which took place after they had attained the height of 19,000 feet. Gay-Lussac, as I have previously mentioned, noted a degree of cold represented by 17·1° F. when he had risen to 23,000 feet. This low temperature was experienced by MM. Barral and Bixio whilst enveloped in the cloud at an elevation of about 19,685 feet; but, as they continued to rise, the cold increased in a most singular and unexpected manner. When near the highest point which they attained, their thermometer sank to −38·2° F., which is 56° below the temperature noted by Gay-Lussac at about the same altitude. The clothes of the observers were covered with fine needles of ice. 'This discovery,' says Arago, in his Report to the Academy, 'explains how these minute crystals may become the nuclei of large hailstones, for they may condense around them the aqueous vapour contained in that portion of the atmosphere where they exist.'

They go far also to prove the truth of Mariotte's theory, according to which these crystals of ice suspended in the air are the cause of halos, parhelia, mock-moons, and mock-suns. Moreover, the great extent of so cold a cloud explains very satisfactorily the sudden changes of temperature which occur in our climates.

Two years after this ascent, Mr. Welsh, of the Kew Observatory, made, under the auspices of the British Association, four ascents in the 'Great Nassau' balloon with the veteran aeronaut C. Green. In August, October, and November, he reached the respective heights of 19,500, 19,100, 12,640, and 22,930 feet, and in each ascent made a valuable series of observations.

But of all the scientific explorations which have been made in the higher regions of the air, the most important are Mr. Glaisher's, as none have ever been performed with greater perseverance, accuracy, and circumspection.

A taste for aerial physics was first developed in this distinguished observer's mind in the years 1829 and 1830, while he was engaged on the principal triangulation of the Trigonometrical Survey of Ireland. In the performance of his duty he was often compelled to remain enveloped in fog for entire weeks, and was thus led to study the colours of the sky, the delicate tints of the clouds, the motion of opaque masses, and the forms of the crystals of snow. On leaving the Survey and entering the Observatory of Cambridge, and afterwards that of Greenwich, his taste did not change. Often between astronomical observations he watched with great interest the forms of the clouds, and often, when a barrier of mists suddenly concealed the stars from view, he wished to know the cause of their rapid formation and the processes in action around them.[1]

No man was better able to appreciate the importance of observations made in and above the clouds, and it was chiefly at his instigation that the British Association turned its attention to this hitherto neglected department of knowledge, and out of its limited means made the necessary grants for several scientific aerial journeys.

In the prosecution of the design, however, a great many difficulties had to be surmounted. It was decided that the ascents should be to the height of four or five miles, in order to verify the facts announced by Gay-Lussac and MM. Bixio and Barral; but on inquiry it was found that no balloon which would contain a sufficient quantity of gas to enable an observer to ascend so high was to be obtained in all England, and, after several unsuccessful and time-wasting trials, it was found necessary to construct a new balloon of sufficient size and strength.

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[1] 'Travels in the Air,' p. 29.

Meanwhile Mr. Glaisher, who, though already advanced in years, had decided on making the observations himself, was occupied with the construction and management of the apparatus which he intended to take with him. He also accustomed himself to the use and manipulation of the instruments in a limited space, and considered how best to group them on a board such as would have to serve him for a table in the car of the balloon; so that when the day for the ascent came he was able to imagine that he was not making his aerial *début*. But in spite of the long experience he had of observations on the earth, and the great attention he had devoted to these preparations, he found that he had neglected a great number of useful precautions and encumbered himself with some superfluous instruments; in short, he was able to perfect his apparatus in every successive ascent, thus proving that scientific investigations in the higher regions are not the business of the first observer that comes.

The novelty of the situation, the rapidity with which all the observations must be made, the limited space at command, the constant strain on the attention, and the fear of not being ready when the moment comes to observe a phenomenon which perhaps no human eye has contemplated before, require the greatest expertness in the use of the instruments and the perfect self-possession of the observer.

Considering all these difficulties and requirements, as well as the comparative inexperience of all previous aeronauts, we may safely affirm that the meteorology of the upper regions of the atmosphere begins with Mr. Glaisher's aerial investigations.

His first ascent took place at Wolverhampton under circumstances which might well have discouraged a less zealous and determined disciple of science. On June 30, 1862, the inflation of the new balloon, which had a capacity of 90,000 cubic feet, and was made not of silk but of American cloth—a material possessed of great strength—was proceeded with, and, after three hours, about 60,000 feet of gas had passed in. At this time the wind arose, and, increasing in fierceness, the balloon, notwithstanding its solid structure, was torn open almost round its widest part. So much injury was done that it took more than a week to repair it, although many persons were employed on the work. After the balloon was repaired, a week's bad weather followed, and as July 17 was the last day Mr. Glaisher's engagements permitted him to remain at Wolverhampton, the filling of the balloon was begun at five in the morning, in spite of a terrible W.S.W. wind which was blowing without intermission. Very great difficulties were experienced in the inflation, and it seemed as if the operation would never be completed. The movements of the balloon were so violent and rapid, that it was impossible to fix a single instrument in its position before leaving the earth—a state of affairs by no means cheering to an aeronautical novice. When Mr. Coxwell, the experienced guide who was to pilot the balloon through the sky, made up his mind at 9 h. 42 m. to let go, the balloon, which had been so impatient to be free, did not rise, but moved horizontally on the ground for some distance, dragging the car on its side—a movement which would have been fatal had there been any lofty building in the way.

Notwithstanding this unpromising beginning, a height of 26,200 feet was attained. Ten minutes after it first rose, the balloon had left the clouds below, and, expanding in the sunshine at the height of 8,000 feet, assumed the shape of a perfect globe. A most magnificent view now presented itself, which, however, Mr. Glaisher was unable to enjoy, as he was still arranging his instruments in the positions they were to occupy, and he had reached an elevation of above 10,000 feet before his apparatus was in working order. At 10 h. 3 m., at an altitude of 12,709 feet, a band of music was heard. Expecting to meet with a temperature below zero before they reached the height of five miles, the aeronauts had made an addition to their clothing, but to their surprise, on ascending from 15,500 to 19,500 feet, the temperature gradually increased from 31° to 42°. Within two minutes after this time, when they had fallen somewhat, it again began to decrease with extraordinary rapidity to 16°, or 27° less than it was twenty-six minutes previously.

Some of Mr. Glaisher's subsequent ascents, as well as the chief results of his numerous meteorological observations, have already been mentioned in previous chapters. We have seen how once, at an elevation never before attained by man, he lost his consciousness, and well nigh fell a victim to his scientific ardour, and how on another occasion he narrowly escaped being precipitated into the sea.

Many future aeronauts will, no doubt, gather laurels in the wide field of observation he has so successfully cultivated, but no other aerial traveller will ever surpass him in self-sacrificing zeal.

CHAPTER XXXVII.

THE BALLOON IN WAR.

The Aerostatic Institute of Meudon—The Balloon at the Battle of Fleurus—Coutelle—The Balloon in Egypt—At the Battle of Solferino—At the Siege of Richmond—The Balloon during the Siege of Paris—Services to be expected from Balloons in Future Wars—Will it ever be possible to Steer them?—Dupuy de Lôme.

WHEN the demons of war are let loose the inventions of peace are forced to minister to their service, and discoveries which should only be conducive to the welfare of man are compelled to assist him in the work of mutual destruction.

Thus in ancient times the burning mirror became in the hands of Archimedes an instrument for setting fire to the Roman vessels before Syracuse, as in our days the electric telegraph has been enlisted among the implements of warfare, and the masterly strategy of Moltke has found an effective auxiliary in Stephenson's locomotive.

Thus, also, while the first French Republic was struggling for its existence with the double eagle of Austria, attempts were made to use the recently-invented air-balloon for warlike purposes. The first trial of its services was, however, by no means encouraging. General Chanal, commandant of the besieged fortress of Condé, wishing to inform the French Government of the straits to which he was reduced, let fly a paper Montgolfière with despatches; but the faithless messenger, instead of delivering them to the right address, carried them to the wrong one, for it was driven by the caprice of the wind right into the enemy's camp.

While Chanal's unlucky balloon thus betrayed his weakness to the foe instead of bringing him assistance from his friends, the chemist Gùyton Morveau, the same who first intro-

UHLANS IN PURSUIT OF A BALLOON.

duced chlorine as a disinfectant, gave the use of the aerostat a more practical turn by advising the Comité du Salut Public to adopt it as a means of reconnoitring. Pursuant to the plan which he proposed, that energetic government decreed the foundation of an aerostatic institute at the formerly royal palace of Meudon. The old lodge served as a manufactory for the preparation of the balloons, and of all the apparatus necessary to accompany them to the armies; the new lodge was appropriated to the institute, and to the accommodation of fifty pupils and of the director and his family. Each of the five armies of the Republic was provided with a balloon from this establishment; but the only one which has ever been mentioned as having been of any service was the 'Entreprenant,' which, under the direction of Coutelle, accompanied the Army of the North.

During the siege of Maubeuge by the Austrians, Coutelle rose in a captive balloon above the town, and sent down his despatches along the rope which held it floating in the air. He thus made daily reports on the progress of the besiegers. When Jourdan invested Charleroi, Coutelle and General Morelot likewise ascended several times in the 'Entreprenant,' to catch a bird's-eye view of the besieged town. At the battle of Fleurus (January 26, 1794) the balloon is said to have played a conspicuous part. Coutelle ascended twice on that day to observe from an elevation of 440 yards the position and manœuvres of the enemy. On each occasion he remained four hours in the air, and by means of preconcerted signals with flags carried on a correspondence with Jourdan. His intended ascent had been made known to the enemy, who at the moment when the balloon began to take its flight opened the fire of a battery against the aeronauts. The first volley was directed too low; one ball, nevertheless, passed between the balloon and the car, and so near to the former that Coutelle imagined it had struck it. When the subsequent discharges were made the balloon had already passed beyond the reach of cannon-shot, and the aeronauts saw the balls flying beneath the car. Arrived at their intended height, the observers, remote from danger and undisturbed, viewed all the evolutions of the enemies, and from the peaceful regions of the air commanded a distinct and comprehensive prospect of two formidable armies engaged in the work of death.

After the battle of Fleurus we again meet with Coutelle at the siege of Mayence, where his balloon was damaged by a storm, and he himself laid up with a fever. His lieutenant now assumed the command of the aerostatic corps, and crossed the Rhine; but the balloon at its first ascent was pierced by the enemy's shot and rendered unfit for use.

After this we hear no more of aerostation in the history of the republican campaigns, and may consequently suspect that the services it is said to have rendered at the battle of Fleurus were greatly exaggerated, and that like so many other warlike inventions, excellent in theory, it was found unfit for practical use.

A few years later a balloon accompanied Bonaparte in his adventurous campaign to Egypt; but the great general, who was at the same time a great comedian, used it less for warlike purposes than to strike the imagination of the Arabs and to acquire the reputation among them of being a wonderful magician.

'A celestial chariot,' said he to the learned muftis who accompanied him into the interior of the great pyramid of Cheops, 'shall ascend by my orders as high as the dwellings of the clouds, and lightning shall descend to the earth along a metallic wire as soon as I give the word of command.'

In pursuance of this grandiloquent boast, Bonaparte caused a balloon to ascend from the great Esbekieh Square at Cairo, on the seventh anniversary of the Republic, and expected the semi-barbarous spectators to be struck with astonishment and awe. But instead of gaining his end he was doomed to meet with disappointment; for the Egyptians and Bedouins assembled on the square saw the balloon ascend with the greatest indifference, and many of them did not even deign to give it a look as it majestically rose into the air. When, after his return from Egypt, Napoleon became the ruler of France, he gave a signal proof of the slight value he attached to the balloon for military purposes by breaking up the Aerostatic Institution of Meudon, which, at the time of its foundation, was deemed so important that no strangers were allowed to visit it.

In 1812 the Russians are said to have constructed an immense aerostat that was to shower down bombs upon the enemy; but it never carried a single soldier into the air.

In 1849 the Austrians intended to make use of the balloon for offensive purposes during the blockade of Venice. They manufactured paper fire-balloons that were to drop shells into the town; but they did not take into account that opposite air-currents frequently blow simultaneously at different heights. Thus their balloons flew at first in the direction of the town, but on rising they returned to whence they came, and dropped their bombs into the Austrian camp.

For the first time since the battle of Jemappes we hear of real services having been rendered by balloons during the American Civil War. In 1862, while the army of the Union was investing Richmond, a captive balloon kept constantly informing General M'Clellan of the sorties that were preparing in the town, and the besieged forces were consequently more easily repulsed.

As the balloon is said to have been of use to Napoleon at the battle of Solferino, it is difficult to conceive why, at the beginning of the campaign that was to prove so disastrous to France, the Minister of War, Lebœuf, refused the offer of an experienced aeronaut to accompany the army. Most probably he thought that the mitrailleuses and the wonder-working Chassepôts were quite sufficient to find the way to Berlin—which, fortunately, proved a more difficult undertaking than was imagined.

The Prussians, on the contrary, accepted a similar offer, which turned out a complete failure; they found, however, the way to Paris, though unassisted by a balloon.

Thus the aerostatic machine has had no influence whatever upon the operations of the vast armies engaged in the gigantic struggles of 1870 and 1871. It has neither helped to gain a battle nor to raise a siege; but while Paris was beleaguered and cut off from all other means of communicating with the world, the balloon still enabled the great city to make known her sufferings and her hopes to the rest of France.

The total number of balloons which left the invested capital was 62, of which 54 were sent out by the Post Office. They carried about 2,500,000 letters, representing a total weight of nearly ten tons. The first balloon, the 'Neptune,' ascended on September 23; the last, the 'Cambrone,' on January 28. All these balloons had, of course, their respective names, and in the list many great men of former days found themselves coupled with strange modern company. Thus we find a Galileo and a Newton associated with a Ferdinand Flocon; an Archimedes with a Gambetta; and a Washington with a Madame George Sand. Some of the balloons, 'Le Kepler,' 'Le Guttenberg,' even bore German names, these illustrious men having probably been mistaken for Dutchmen.

Besides letters, despatches, and some absurd proclamations addressed to the German army, and in the name of universal brotherhood inciting the soldiers to revolt, the balloons carried pigeons, intended to bring back news and replies to the outgoing letters. Some of these birds returned on the day of departure, some after two or three days, and others after long intervals. Several came back injured by birds of prey, others wounded by shots; for the besieging army was as anxious to prevent the pigeons returning to Paris as it was to stop the balloons leaving it. Whenever the latter came within sight of the Prussians, a well-sustained fire was opened against them, and it was only at a height equal to that of Snowdon or Ben Nevis that the travellers felt secure against the enemy's shot. A special gun was fabricated by Krupp for the purpose of hurling projectiles to a height of 10,000 feet; but Paris must have surrendered before it could be brought into action, for we have never heard of its having been used. The voyage of many of the balloons was a mere pleasure trip, as they safely crossed the Prussian lines and landed their passengers and letters beyond the enemy's reach; others again fell in his power, and the luckless aeronauts were led into captivity. It was even a matter of some deliberation whether they should not be treated as spies and shot accordingly; but as the case had of course not been thought of by Hugo Grotius and Puffendorff, the great expounders of the laws of nations, they were allowed to enjoy the benefit of this omission. Among the men who left Paris by this aerial road we find, besides some well-known aeronauts, such as Fonvielle, Tissandier, Godard, Duruof, &c., a great number of sailors—a circumstance which does honour to the French navy; and last, not least, M. Gambetta, whom part of his countrymen call a patriot, and others a 'fou furieux.' Very long voyages were made by some of the balloons: 'La Ville de Paris' flew to Solingen in Rhenish Prussia, where a few years before M. Flammarion had landed under very different auspices; the 'General Chanzy' was driven by the aerial currents as far as Munich; and 'La Ville d'Orleans' was even carried to the unprecedented distance of 600 miles, beyond Christiania in Norway. It seems that of all the balloons which left Paris but two are unaccounted for. One of these, the 'Jacquard,' manned by a sailor named Prince, was seen sailing westwards over the British seas towards Newfoundland. Despairing, perhaps, of his personal safety, but mindful of Nelson's Trafalgar motto, the gallant fellow dropped a letter-bag, which was picked up and delivered by some fishermen. He then vanished into space, never to reappear in this world.

The fate of the other aeronaut, M. Lacaze, who likewise ascended alone in the 'Richard Wallace' just before the capitulation, is shrouded in similar mystery. Near Rochefort he was spoken to by some peasants, and advised to stop, but wishing to get nearer to Bordeaux he disregarded their prudent recommendation, and when last seen was drifting out seawards in a south-westerly direction. How or where he perished is a secret which probably will never come to light.

The following extract from an article by Herr Hans Wachenhusen, the military correspondent of the 'Kölnische Zeitung' during the war, gives an account of the services which the balloon may be expected to render in future campaigns. 'Reconnoitring, the obtaining of trustworthy intelligence is an essential object in war. Its having been so grossly neglected by the French generals was one of their greatest faults. But experience teaches that the reports of patrols and scouts are frequently but little to be relied on. Some men are too cautious, others too careless, and thus it is often extremely difficult to sift the truth out of conflicting accounts.

If we had had a balloon at our disposal before the French attacked us at Saarbruck, it would have been easy to reconnoitre the whole country as far as Metz, and to obtain an accurate view both of the advance and of the retreat of the enemy.

'What services might not the balloon have rendered during the sieges of Strasburg, Metz, and Paris, or during the three days before the battle of Gravelotte! How easily might it have been posted beyond the reach of the enemy's guns, and how well it would have informed us whenever he was preparing for a sortie!

'To procure at all times the necessary gas seems more difficult than it really is. The apparatus necessary for its preparation, and the transport of the balloon and all its appurtenances, would require but a small number of waggons, and, considering the immense sums absorbed by war, the expense would not be worth mentioning.

'Fancy a captive balloon floating in the air during a battle. A staff-officer overlooks from its car an area extending over an immense surface; every inequality of the ground is open to his view, he at once perceives every movement, every advantage, or every weakness of the enemy, and the commander-in-chief directs his operations according to the despatches which he is constantly receiving from the aerial observer.

'It may be objected that guns of a wide range would endanger the balloon, and that in case of its being struck the general would then be at a loss for information; but this danger is not much to be feared. The horizon commanded by a balloon at the height of 1,000 or 1,500 feet is so vast that it cannot be difficult to place it out of gun-reach. In a decisive battle, moreover, a reserve balloon might easily be held ready for any emergency.'

Whether Herr Wachenhusen is not rather too sanguine in his expectations, the future will show, for the trials hitherto made have assuredly not been the last. To have a filled balloon always in readiness when or where required, is probably not quite so easy as he imagines; and it must also be considered that, while a free balloon glides gently through the air, a captive balloon is perpetually exposed to considerable oscillations, which, to say nothing of the clouds of smoke and dust raised by the turmoil of battle, must render reconnoitring a rather difficult task.

Were it possible to guide a balloon, as a mariner guides his ship, its utility would of course be enormously increased, and we then might live to see the aerial scouts of contending armies pouncing upon each other in the atmosphere like birds of prey, or enjoy the pleasure of reading 'our own correspondent's last news from the field of battle,' dated from the clouds. Every great conflict on earth would then be preceded or accompanied by light skirmishes in the air; but it seems extremely doubtful whether this dream of sanguine aeronauts will ever be accomplished. The difficulties of constructing a machine uniting considerable powers of propulsion with the utmost attainable lightness—a combination involving contradictory qualities, and yet absolutely necessary for cleaving the resisting air, for defeating adverse winds, and at the same time bidding defiance to the earth's attraction—are so immense that in spite of the prediction of Mr. John Wise, 'that, by means of an aeronautic machine, our children will be able to travel to all parts of the earth without being troubled by steam or sea-sickness, and with a rapidity of twenty geographical miles in an hour,' we must be allowed to remain incredulous until the first successful aerial voyage from one fixed point to another—were it only from Hyde Park to the Crystal Palace—shall have been realised. The experiments undertaken by Dupuy de Lôme at the expense of the French Government, in the fortress of Vincennes, show at all events that the 'grande nation' would willingly enlist the services of a manageable balloon, so as to be able in the next 'guerre de revanche' to reconnoitre the movements of the German armies without being disturbed by inconvenient Uhlans. But as the leading military authorities in Prussia have likewise decided on the formation of an aeronautic corps, the French, supposing the invention to be made, will not have the empire of the air all to themselves; and while casting inquisitive glances from on high into the enemy's camp, they must expect to have their own strategic movements surveyed in a similar manner.

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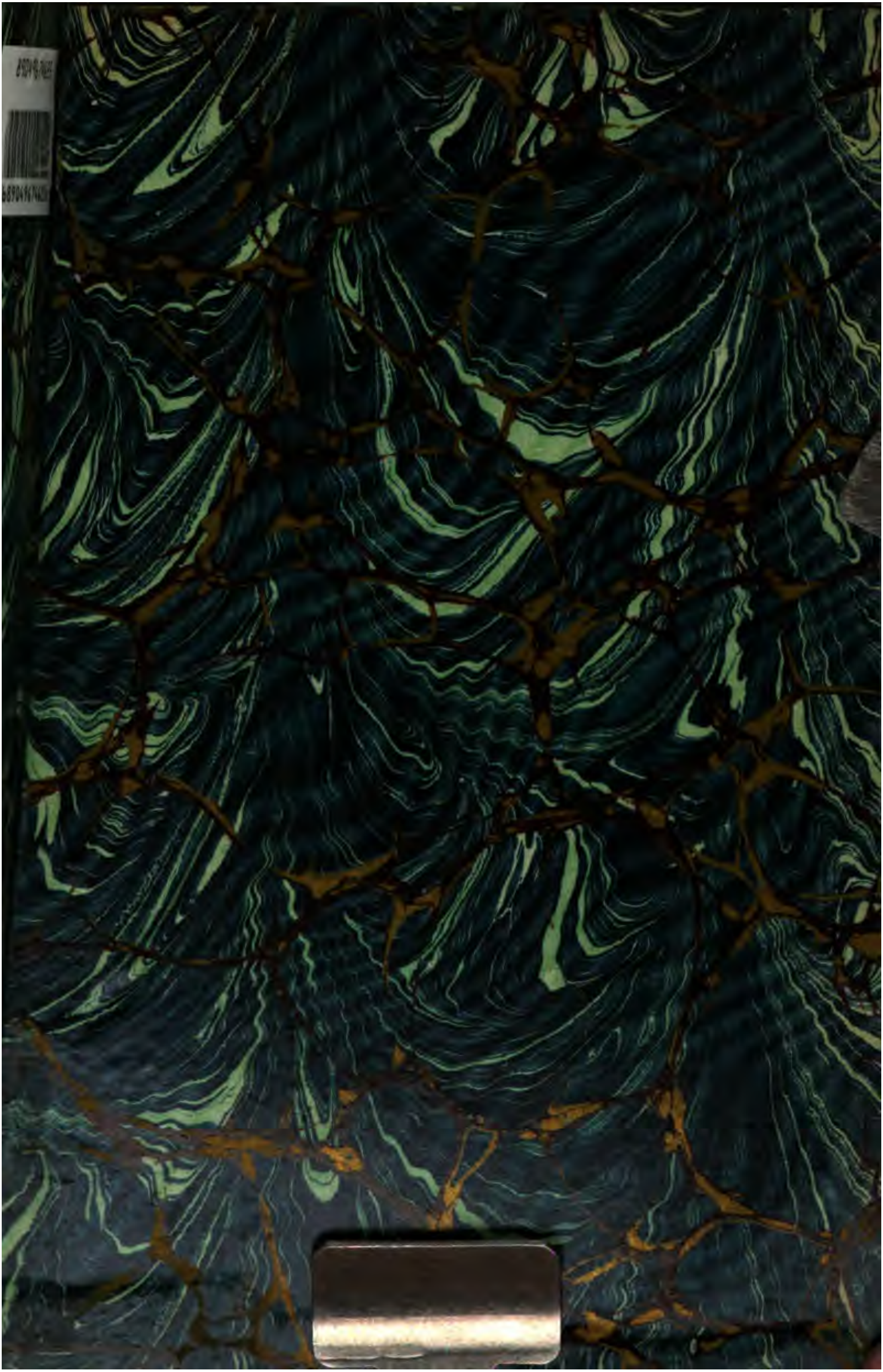

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